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COMBUSTION

DEVOTED TO THE ADVANCEMENT OF STEAM PLANT DESIGN AND OPERATION

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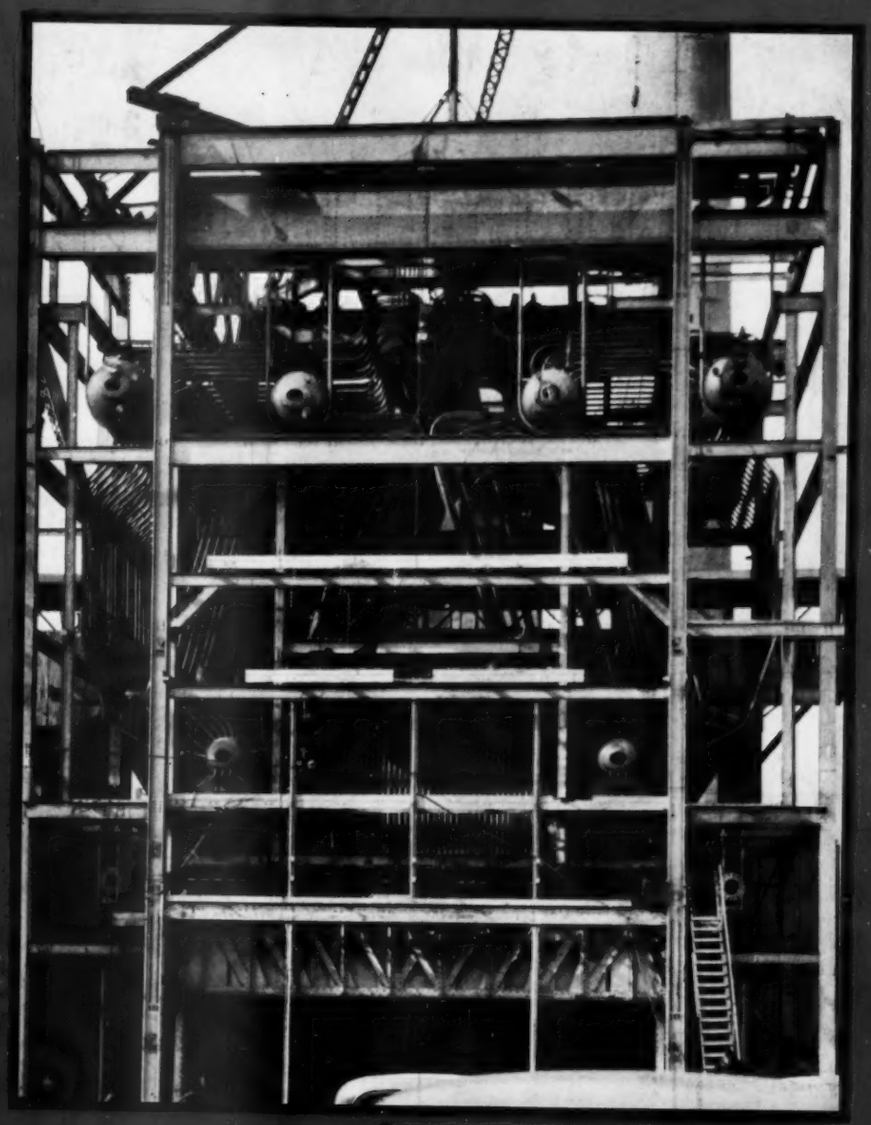
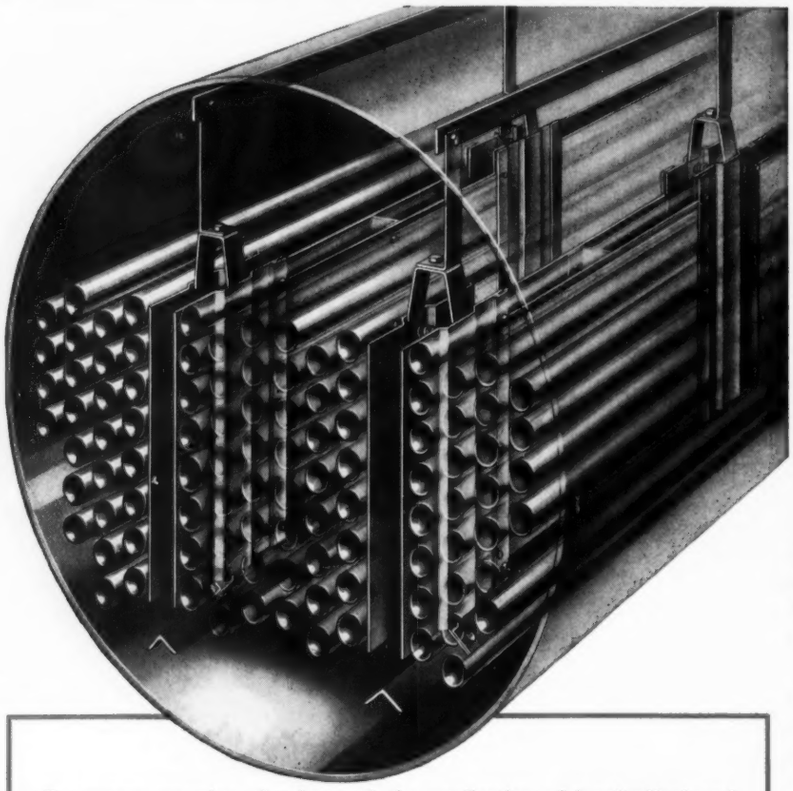


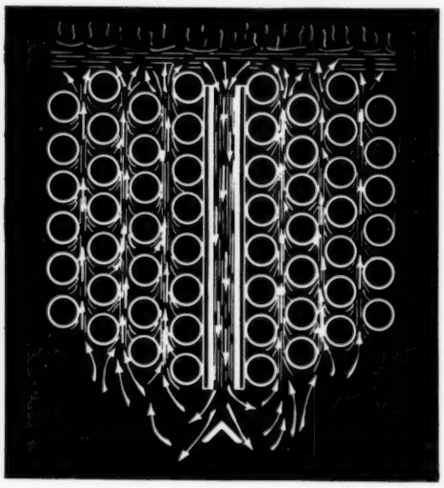
Construction view of 1,000,000-lb per hr unit at Logan Station before closing end wall

Superposition at Schuylkill Station of Philadelphia Electric Company

Boiler Baffling Arrangements

All Fire Tube Boilers
ARE NOT EQUAL





By proper grouping of tubes and the application of longitudinal and transverse baffles, as illustrated above, the C-E Nuway Boiler adds to the conventional hrt boiler design a very definite control of circulation and thus achieves an extremely desirable result in a relatively simple manner.

The baffles provide areas in which the circulation is definitely downward, unimpeded by the upward circulation produced by steam formed at the heating surface of the tubes. Upward circulation is confined to the space occupied by the tubes, which results in high vertical velocity with consequent high efficiency of heat transfer and rapid steam release.

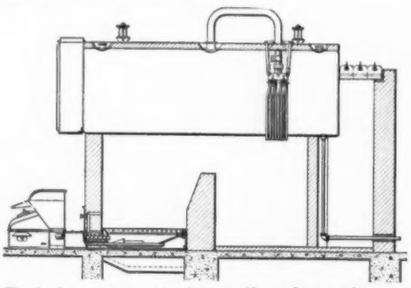
This superior design feature assures these advantages:

1—Ability to carry sustained overloads

2—Quick response to fluctuating loads

3—Maximum heat absorption—High Efficiency

4—Dry steam at higher ratings



Typical arrangement of a small modern unit comprising a C-E Nuway Boiler equipped with Elesco Girth Type Superheater, and fired by a C-E Skelly Stoker-Unit.

There exists in the minds of many, a more or less definite impression that all fire tube boilers, like all men referred to in a famous American document, are created equal.

If applied to boilers of the riveted type as constructed under the A.S.M.E. Boiler Code by a relatively large number of reputable manufacturers, there is probably a considerable element of truth behind the impression.

But fabrication methods have improved. It is now possible to buy boilers of completely welded construction which have an obvious advantage in that there are no seams to leak or provide a starting point for corrosion and caustic embrittlement. Combustion Engineering is one of a relatively few manufacturers of fire tube boilers having the facilities and experience required for Class 1 Fusion Welding.

And when to this modern method are added distinct improvements which assure effective control of circulation with a resulting increase in capacity and efficiency, there can remain no question as to the importance of careful inquiry into the relative merits of fire tube boiler design and construction.

All fire tube boilers are NOT equal! One type is definitely better—The C-E Nuway with its all-welded construction and its exclusive method of controlled circulation. Send for new catalog describing its advantages.

A-357a

COMBUSTION ENGINEERING COMPANY, INC.

200 Madison Avenue, New York, N. Y. ***Canadian Associates, Combustion Engineering Corporation, Ltd., Montreal***

C-E PRODUCTS include all types of Boilers, Furnaces, Pulverized Fuel Systems and Stokers; also Superheaters, Economizers and Air Heaters.

COMBUSTION

DEVOTED TO THE ADVANCEMENT OF STEAM PLANT DESIGN AND OPERATION

VOLUME EIGHT NUMBER TWELVE

CONTENTS

FOR JUNE 1937

FEATURE ARTICLES

Superposition at Schuylkill Station of Philadelphia Electric Company	*by E. L. Hopping*	22
Boiler Baffling Arrangements	*by W. S. Patterson*	29
Boiler Inspectors Meet at New York		35
Boiler Code Proposals and Welding Research	*by Dr. D. S. Jacobus*	35
Forced-Circulation Boilers	*by H. B. Oatley*	35
Developments in Steam Generating Units	*by John Van Brunt*	37
Operation of Large Modern Steam Generating Units	*by E. H. Krieg*	37
Prevention of Furnace Explosions	*by E. G. Bailey*	38
Maintaining High Standards for Welded Vessels	*by A. C. Weigel*	39
Welding High Tensile Strength, Low Alloy Steels	*by Dr. J. C. Hodge*	39
Non-Destructive Testing of Welds	*by Dr. Comfort A. Adams*	40
Fuel Utilization in New York City	*by Arthur C. Stern*	41

EDITORIALS

Canadian Engineers Celebrate Semi-Centennial	21
Where National Defense Dominates Engineering Thinking	21
The Engineer and Labor Problems	21

DEPARTMENTS

Steam Engineering Abroad	43
Review of New Books	46
Advertisers in This Issue	48
General Article Index—(Vol. 8, Nos. 1 to 12)	49

H. STUART ACHESON, *Advertising Manager*

ALFRED D. BLAKE, *Editor*

THOMAS E. HANLEY, *Circulation Manager*

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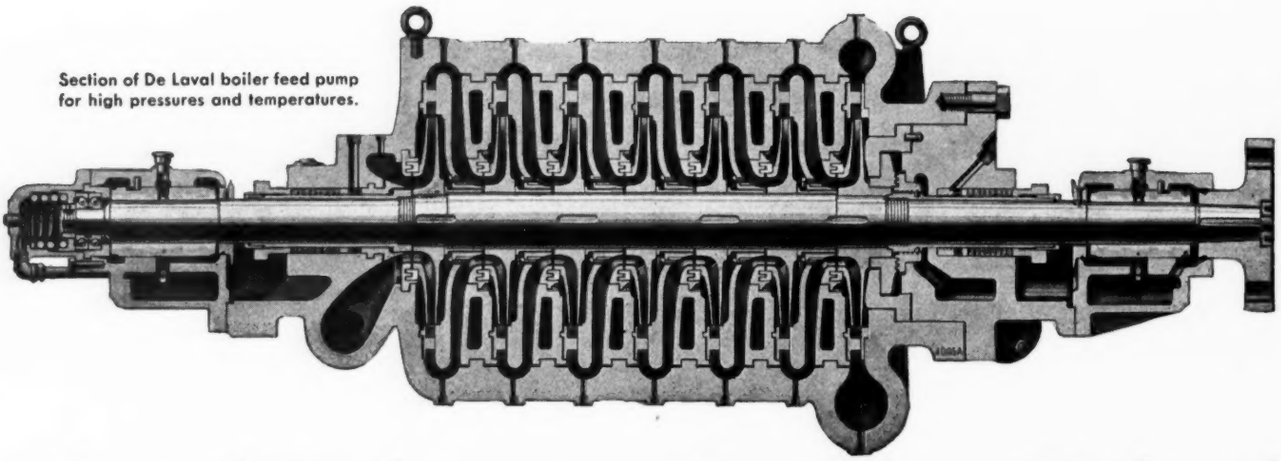
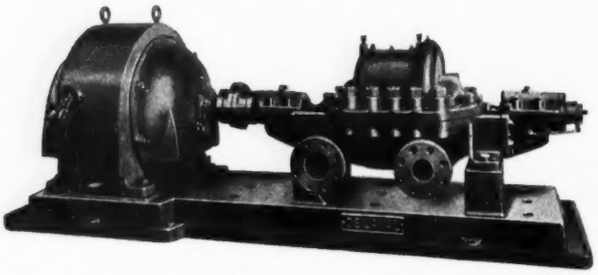
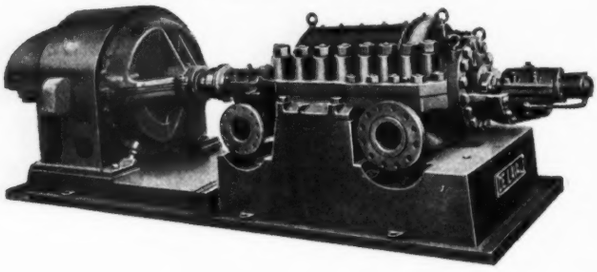


Section of De Laval boiler feed pump for high pressures and temperatures.

Axial Balancing Problem Solved in DE LAVAL BOILER FEEDERS



Four-stage boiler feeder; 700 gal. per min. of water at 340° F., raised in pressure from 180 lb. per sq. in. suction pressure to 550 lb. per sq. in. discharge pressure, at 1760 r.p.m.



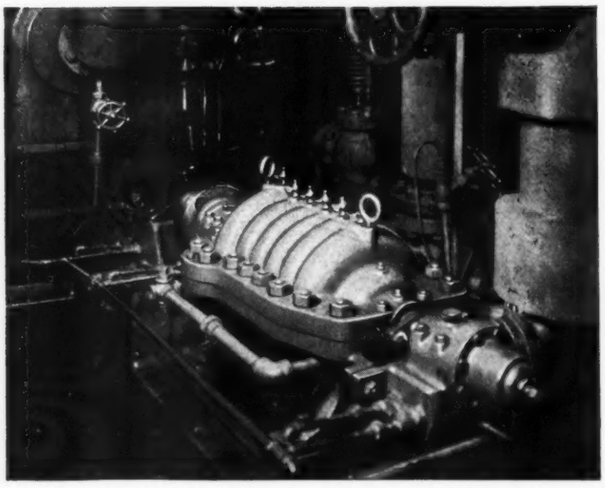
Six-stage boiler feeder; 800 gal. per min. of water at 227° F. against 850 lb. per sq. in.

The hydraulic full automatic balancing system used in De Laval multistage pumps balances all axial thrust under all conditions of operation and prevents metallic contact of moving and stationary elements. A thrust bearing is unnecessary with the De Laval balancing system. The axial bleed-off bushing, which controls leakage, is subject to a comparatively small drop in pressure and there is very little wear.

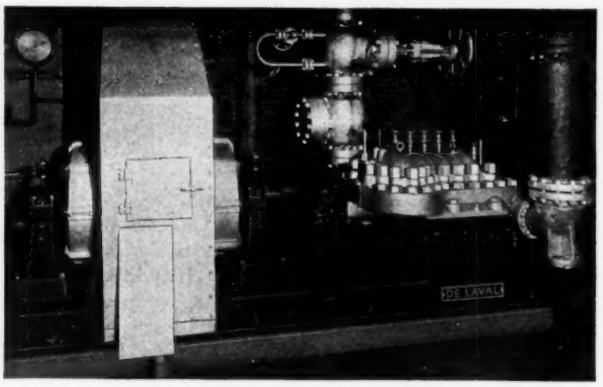
De Laval boiler feed pumps have been supplying boilers at pressures up to 1400 lb. continuously for years without shutdown due to any difficulties with the hydraulic balancing system.

The design of centrifugal pumps for feeding water at high temperatures to boilers under high pressures is discussed in Leaflet C, which will be sent upon request.

DE LAVAL STEAM TURBINE CO.
TRENTON, NEW JERSEY



Turbine driven boiler feeder installed on a modern oil tanker; 105 gal. per min. of water at 230° F. against 485 lb. per sq. in.



Turbine driven boiler feeder delivering 800 gal. per min. against 1400 lb. at 3500 r.p.m. Water at 210° F. enters the suction under 325 lb. pressure.

3602

EDITORIAL

Canadian Engineers Celebrate Semi-Centennial

With two-day sessions each at Montreal and at Ottawa the Engineering Institute of Canada is this week celebrating its Semi-Centennial. Participating are representatives from most of the important British and American engineering societies as well as officials of the Canadian Government. An extensive technical program dealing with hydro developments, Canadian coals, power plant performance, transportation and electrical applications is supplemented by visits to numerous plants and to points of historic and scenic interest, with which that locality abounds.

Inasmuch as Canada covers an area greater than that of the United States, with a population less than one-twelfth as great, and much of that agricultural, industrial development has been less. Hence fewer specialized engineering societies have come into existence and the major professional engineering activities have centered within the Engineering Institute. Its constructive work toward technical advancement in Canada is perhaps not as well known to American engineers as it might be. There is opportunity for still closer cooperation between the professional societies on the two sides of the "Border," which, in fact, may be regarded as nonexistent in so far as engineering matters are concerned.

The present celebration marks a fitting milestone in the engineering progress of our Canadian neighbors and may the Institute's next fifty years be replete with accomplishments.

Where National Defense Dominates Engineering Thinking

While the necessity for fitting new boiler capacity into existing steelwork of old stations sometimes taxes the ingenuity of designers, American engineers, happily, are not confronted with the added necessity of safeguarding against aerial attack as at present seems to be uppermost in the minds of many Continental designers. That this idea permeates engineering thinking in certain European countries is apparent from a perusal of current articles in the technical press of those countries.

For instance, a recent issue of *The Brown Boveri Review* contains a layout for a 20,000-kw Velox boiler and turbine plant arranged for installation in a bombproof excavation in rock having a section similar to that of a two-track railway tunnel. Commenting on the design the article says that such units "have a considerable future in the design of bombproof stations which are unfortunately a problem with us today."

In contrast with American practice, relatively few new German boiler units are of large capacity, the idea being not to place "too many eggs in one basket," as regards vulnerability from attack. One large German works recently made substantial additions to its power facilities, but instead of increasing its central plant, as would appear most economical from the investment and operating angles, the new capacity was installed in two additional and widely separated plants interconnected by both an electric and a steam grid, with the avowed purpose of guarding the works against complete shutdown in case of attack from the air. It is understood that all new power plans have to receive governmental approval from the standpoint of national security.

A prominent German engineer writes concerning a suggested article on his new power plant: "It will not be new to you when I tell you that the European conditions, particularly for my own somewhat isolated country, are not without great dangers despite our great abhorrence of warlike complications, and for this reason our government does not want to have published any reports concerning newer plants and structures. This is one of the tasks of the present defense against air attacks."

Many similar instances could be cited, as well as the fact that in power plant construction the use of strategic materials, from the standpoint of national defense, is being given intensive study.

One may truly question whether the continual fostering of such fears is not the surest path to their fulfillment. It is a pity that engineering thought should be fettered by conditions wrought from political policies. It is to be hoped that American engineering practice will continue unhampered by such considerations.

The Engineer and Labor Problems

"The nation must turn to the engineer to solve the problems of labor and industry," said Gano Dunn, president of the J. G. White Engineering Corporation, in addressing this year's graduating class at Massachusetts Institute of Technology. Adding that, "The engineer finds himself in a pivotal position in industry, intermediate between capital and labor, and is in a position to understand, interpret and judge," Mr. Dunn visioned an opportunity for social service which members of the older professions do not possess.

The idea has often been advanced that the engineering method of approach and the habit of factual investigation makes the engineer especially fitted to cope with problems of social and public concern. Granted that this is true, the fact remains that, as individuals, few engineers take to such service; or it may be that politically dominated public service does not take to the engineer, as a check-up of the personnel now engaged in many governmental activities will reveal.

Mr. Dunn's advice to the graduates would be easier of accomplishment were the present difficulties confined to the managements and labor directly concerned, but with outside dictation and such influences as now exist it is believed that the engineering method of approach and analysis would be of little avail.

SUPERPOSITION at S

The high-pressure extension to the Schuylkill Station consists of two 600,000-lb per hr bent-tube boilers, equipped with economizers, air heaters and slagging-bottom furnaces, supplying steam at 1350 lb pressure, 910 F total steam temperature, to a 50,000-kw 3600-rpm turbine-generator with hydrogen cooling. The high-pressure turbine will exhaust primarily to three existing low-pressure units of 85,000 kw combined capacity. Scheduled for base-load operation, the superposition is expected to reduce the station heat rate to approximately 11,800 Btu per kwhr.

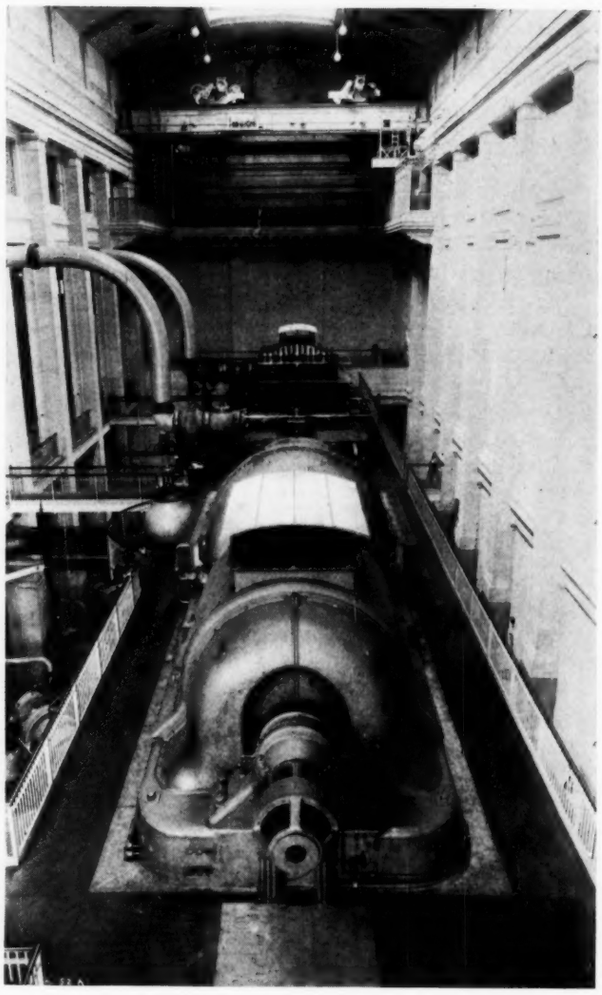


Fig. 1—Turbine hall showing 30,000-kw unit (No. 8) in foreground and 35,000-kw unit (No. 9) in background

THE Philadelphia Electric Company System supplies electric service to an area of about 2100 square miles in southeastern Pennsylvania and a small portion of northern Maryland and serves a population of approximately 2,800,000. A territory so thickly populated contains a huge residential market. In addition, requirements for industrial power are vast, as Philadelphia and its immediate area are a large manufacturing center with industries of highly diversified nature.

A metropolitan area of this size and character places a challenging responsibility on the utility serving it. Unfailing electric service at a reasonable cost must be available to meet any possible demands from the smallest residential customer to the largest industrial plant. The Philadelphia Electric Company has continually recognized and met this responsibility by progressively enlarging its systems on a sound economic basis. This has been effected solely through private initiative and capital. Progressive management and consistently low electric rates for all classes of service have built up an electric load which reached an instantaneous peak in December 1936, of 831,000 kw.

The capacity of the Philadelphia Electric system, embraced in seven principal generating stations, totals over one million kilowatts. Outstanding among these stations are, the Conowingo Hydroelectric Plant located on the Susquehanna River, approximately sixty miles from Philadelphia, which has an installed capacity of 252,000 kw; the Richmond Steam Station located seven miles northeast of City Hall, which contains, among several units, a 165,000-kw turbine-generator installed during 1935; and the Deepwater high-pressure steam station, located on the New Jersey side of the Delaware River opposite Wilmington. Included within this category will again reappear the Schuylkill Station at 27th and Christian Streets, one-and-a-half miles southwest of City Hall.

At present the Philadelphia Electric Company supplies service for both the Reading and the Pennsylvania Railroad suburban lines radiating from Philadelphia, and also energy for a large part of the 230-mile main line system of the Pennsylvania Railroad between New York and Washington, now completely electrified for both passenger and freight traffic. The Company also supplies the energy for the operation of the traction system in Philadelphia and many of the outlying communities. The maximum hour demand on the system for railroad and traction service is over 200,000 kw.

The Management early recognized the advantages of interconnection on an extensive scale with the neighboring systems of the Public Service Electric & Gas Company and the Pennsylvania Power & Light Company, and it pioneered in forming the 220-kv Pennsylvania-New Jersey interconnection of the three companies, which comprises a power pool in excess of two million kilowatts capacity, serving nearly two million customers.

SCHUYLKILL STATION of Philadelphia Electric Company

By E. L. HOPPING
Mechanical Engineer,
Philadelphia Electric Company

Fig. 3 shows the main transmission system and generating stations of the Philadelphia Electric Company System. It will be noted that Schuylkill Station occupies a strategic position in this area.

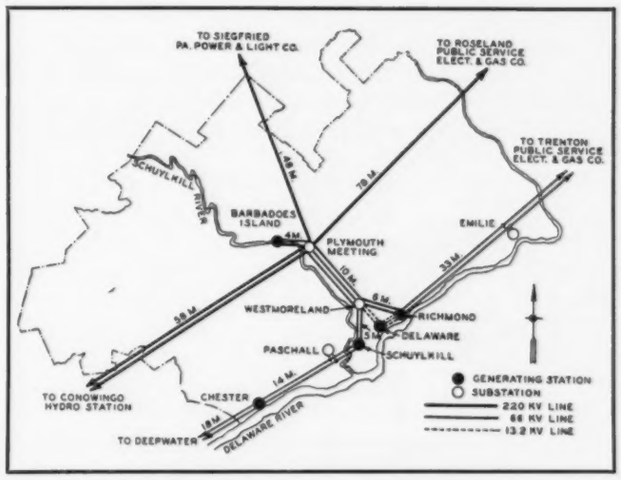


Fig. 3—Main transmission system and generating stations of the Philadelphia Electric Company

Description of the Schuylkill Project

Investigations showed that the next step in increasing the capacity should be at Schuylkill Station. The station was built in 1903 and enlarged in 1912. During 1914 and 1915 there were installed two steam turbine-generators, of 30,000 and 35,000 kw capacity at that time the largest of their kind. The later installation of a 20,000-kw unit and various station alterations made an available station capacity of 129,000 kw.

These three turbines, originally designed for approximately 215 lb per sq in. gage and 150 F superheat, offered an ideal condition for an addition in plant capacity and an appreciable increase in thermal efficiency through the medium of superposition. With this form of plant rehabilitation, capacity in this important load area could be effectively reinforced. Accordingly, the program provided for the installation of a 50,000-kw high-pressure, high-temperature turbine-generator, with its complement of boilers, exhausting primarily to the existing 35,000-kw, 30,000-kw and 20,000-kw low-pressure units. This arrangement would schedule the station for base-load operation.

During 1936, the station heat rate was 31,592 Btu per net kwhr with a load factor of only 5.1 per cent and a capacity factor of 2.5 per cent. The best yearly heat

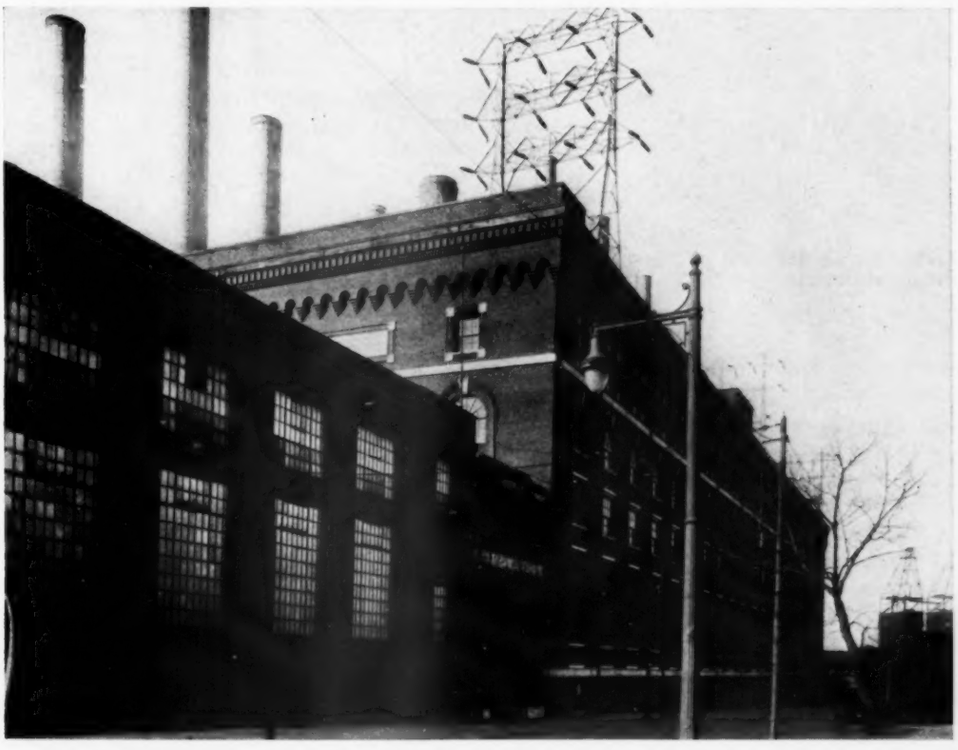


Fig. 2—Schuylkill Station facing Christian Street

rate of the three aforementioned units was approximately 22,000 Btu per net kwhr. With the addition of the 50,000-kw high-pressure unit this rate will be reduced to approximately 11,800 Btu per net kwhr.

The plan at Schuylkill, as is the case with most superposed installations, utilizes existing land, building and transmission equipment, intake and discharge tunnels, condensing facilities and the partial use of the coal and ash handling system.

Circulating water requirements at this location presented a major problem when considering new capacity. The plant, located two miles below a dam, above which city water requirements are taken, is forced during certain periods to rely on surface evaporation of the pond for cooling effect. Tide flows also cause a backing up of warm water at this location. Under such conditions a high-pressure, non-condensing unit demanding no additional circulating water is especially desirable.

The replacement of a group of old and inefficient low-pressure boilers by new and efficient steam generating units results in considerable savings in fuel, labor and maintenance. It is estimated that the operating savings at Schuylkill Station will fully justify the additional investment to be incurred.

In the choice of superposition for Schuylkill Station careful consideration was given to these and other factors, the more important of which are: recent developments in 1200 to 1400 lb, 900 to 925 F equipment, high availability for both boilers and turbine, system reinforcement and improved reliability in this area, better thermodynamic performance, space limitations and circulating water restrictions.

Fig. 4 is a plan view of the station. No. 6 vertical condensing unit of 15,000 kw capacity is being replaced by the new 50,000-kw unit. The original boiler house, No. 1, comprised forty low-pressure boilers on two floor elevations. Twenty-four of these boilers are being replaced by two 600,000-lb per hr high-pressure steam generating units with their associated auxiliaries and pulverizing equipment. The pressure and temperature for the two new boilers, Nos. 23 and 24, were chosen so that the exhaust conditions of the new turbine, designated as No. 3, will approximate present initial conditions for the older turbines, namely Nos. 5, 8 and 9. The new 50,000-kw high-pressure turbine, designated as No. 3, replaces a vertical condensing unit of 15,000 kw capacity (not shown).

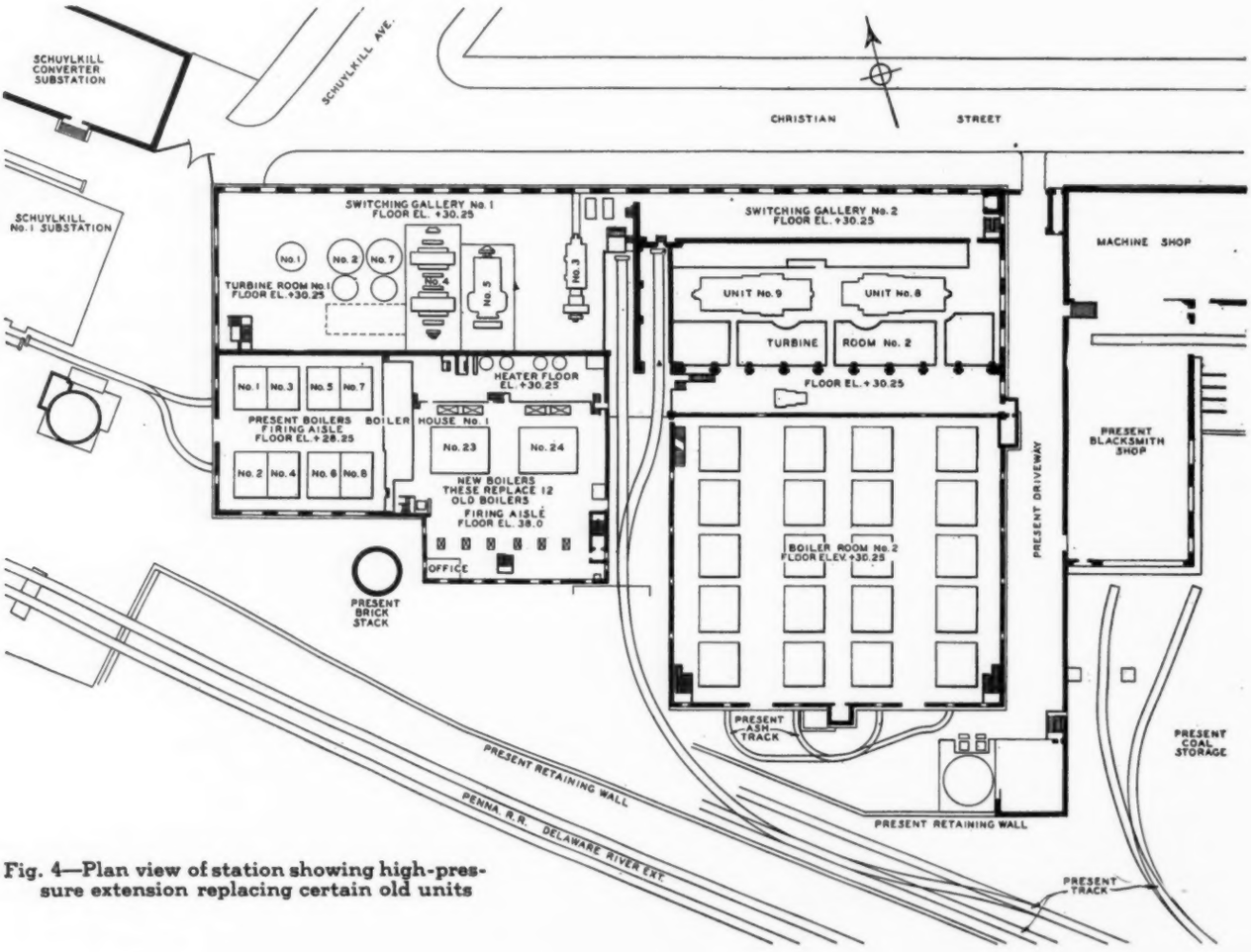


Fig. 4—Plan view of station showing high-pressure extension replacing certain old units

The Turbine-Generator

The turbine will be rated at 50,000 kw, 3600 rpm, and is a combination impulse-reaction, single-cylinder unit designed for 1250 lb gage pressure and 900 F total temperature (max. 1300 lb gage and 925 F on swings)

and will exhaust against a back pressure of 230 lb gage. It will exhaust into the present steam header system of the station supplying steam for operation of existing units Nos. 5, 8 and 9. No. 5 unit is a 20,000-kw, 25-cycle, 1500-rpm machine. No. 8 is a 30,000-kw, 25-cycle, 1500-rpm unit, and No. 9 a 35,000-kw, 60-cycle, 1200-rpm unit. These turbines were designed for 215-lb per sq in. gage and 150 F superheat. Normally these machines will operate at or near their most economical load, the 50,000-kw high-pressure unit being selected for such loading.

Exhaust pressure of the high-pressure unit will be controlled by means of a pressure regular set to maintain a constant steam pressure of approximately 230 lb gage at the exhaust.

There will be one impulse element, consisting of one pressure and two velocity stages, followed by fourteen reaction stages. The nozzles and blading will be of stainless steel, the cylinder a carbon molybdenum steel casting and the spindle a nickel-chrome-molybdenum forging.

The generator is rated at 50,000 kw, 85 per cent pf, 13,800 volts, 3 phase, 60 cycles. The generator field excitation will be obtained from a direct-connected 165-kw 250-volt shunt-wound main exciter and a 3-kw, 250-volt pilot exciter, both of which are air cooled. The generator cooling system will be the closed-circuit type in which hydrogen will be circulated by means of two internal propeller type fans mounted on the shaft, and the recirculated hydrogen will be cooled by means of surface coolers located inside the generator housing. Water for the coolers will be chlorinated Schuylkill River water.

Steam will be admitted to the turbine through a 20-in. nominal diameter throttle valve via two 14-in. inlet pipes. Two 12 in. lines, one from each boiler, supply these inlets. The throttle will be welded into position between the boilers and inlet piping. The entire valve is placed below the floor level with only the operating handwheel and its stand appearing above the floor, and the hydraulic-operated mechanism is placed below the steam valve, thus reducing to a minimum the fire hazard of oil coming in contact with high-temperature steam parts.

The overall dimensions of this 50,000-kw Westinghouse unit, including turbine, generator and exciter, are: length of unit proper 44 ft 8 in., length including throttle valve 56 ft 9 in., width 12 ft 4 in., height 9 ft 7 in.

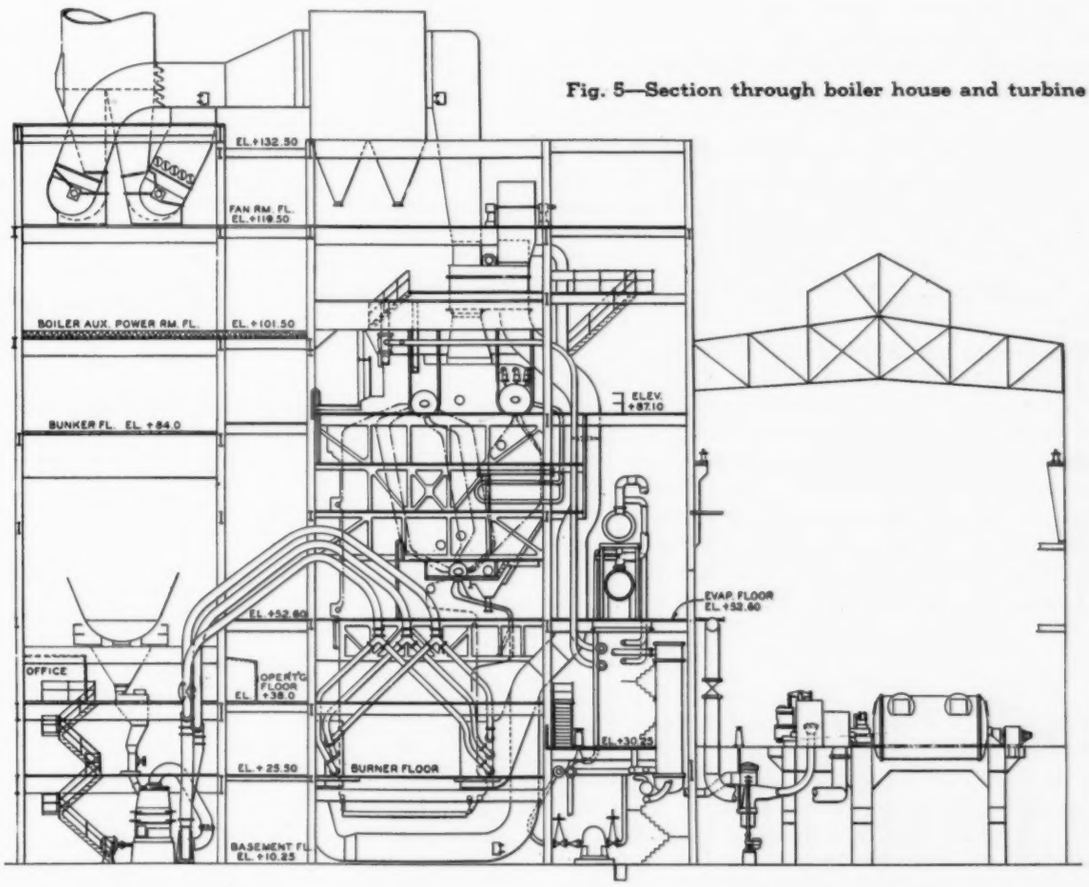


Fig. 5—Section through boiler house and turbine hall

The Boilers

Steam requirements for the high- and low-pressure units dictated the selection of two 600,000-lb per hr boilers supplying steam at a pressure of 1350-lb per sq in. gage and 910 F. Fig. 5 is a cross-section through the boiler house and the turbine hall and Fig. 6 is a section through the boiler and furnace. These Combustion Engineering Company boilers are of the bent-tube type and are arranged for pulverized coal firing. There are three main drums, the upper rear drum being provided with an internal-type steam washer. Unit firing of the corner-tangential type is employed. Each boiler contains twelve burners, three per corner, the burners being adaptable

also for either oil or gas firing, and oil will be used for starting or bringing the units up to pressure. The boilers are equipped with conventional continuous-loop economizers with the gas flow up through the economizer and the water flow down through the tubes.

The superheater raising the steam temperature to 910 F maximum is located between the first and second tube banks. Each unit will be supplied with a bypass damper for control of superheat which will be capable of maintaining the total temperature of the steam within the range of 910 F plus or minus 10 F from three-quarter load to full load. The furnace bottom is designed for continuous slag removal.

For each boiler two induced- and two forced-draft fans and two air heaters of the continuous regenerative counterflow type are located as shown in the cross-section. The fans will be driven through hydraulic couplings for variable-speed control. Each induced-draft drive is 1000 hp and each forced-draft drive is 350 hp. Two induced-draft fans in operation will discharge 375,000 cfm of 385 F gas against a static pressure of 23 in. wg and two forced-draft fans in operation will supply 205,000 cfm of 95 F air against a static pressure of 14 in. wg.

The unit system of fuel pulverization is employed. Three bowl type mills, each of 15 tons per hr capacity, are provided per boiler, the mills and mill exhausters are of the integral type, driven by 250-hp motors and the fans are the open wheel type, having removable flange steel blades.

The furnace heat release will be 27,300 Btu per cu ft per hr, based on an effective furnace volume of 27,300 cu ft.

The urban location of Schuylkill Station led to the selection of electrical precipitation for the collection of fly ash from the boilers. These precipitators are located between the air heaters and the induced-draft fans. Each unit comprises three sections in width and two sections in depth. In addition, low gas velocities through ducts, breeching and stacks should preclude the possibility of any dust nuisance in the plant area.

Heat Balance

The heat balance arrangement as indicated in Fig. 7 provides for variable-speed steam-driven boiler feed pump turbines with a bleeder attachment to the second heaters and constant-speed turbine-driven tank pumps. The existing low-pressure units Nos. 8 and 9 are bled to the first-stage heaters. The location of the tank pump in the discharge line from the deaerator and the boiler feed pump in the discharge from the third heater eliminates the use of high-pressure heaters and associate equipment. Three boiler feed and three tank pumps are provided, two of each being sufficient for full load operation of the equipment.

The three non-condensing extraction steam turbines for driving the variable-speed boiler feed pumps are designed for normal steam conditions of 215-lb per sq in. gage and 517 F total temperature with 5-lb per sq in. gage at the exhaust. Both speed and bleeder pressure are variable. The turbines have six single-row pressure stages with a bleeder opening between the first and second stages, and they are designed to develop 1035 hp maximum non-bleeding; bleeding they are rated at 2000 hp.

The three non-condensing steam turbines for driving the constant-speed 3500-rpm tank pumps are designed for normal steam conditions of 215-lb per sq in. gage and 517 F total temperature with 5-lb per sq in. gage at the exhaust. One two-row velocity stage is followed by three single-row pressure stages. The turbines are each rated at 390 hp.

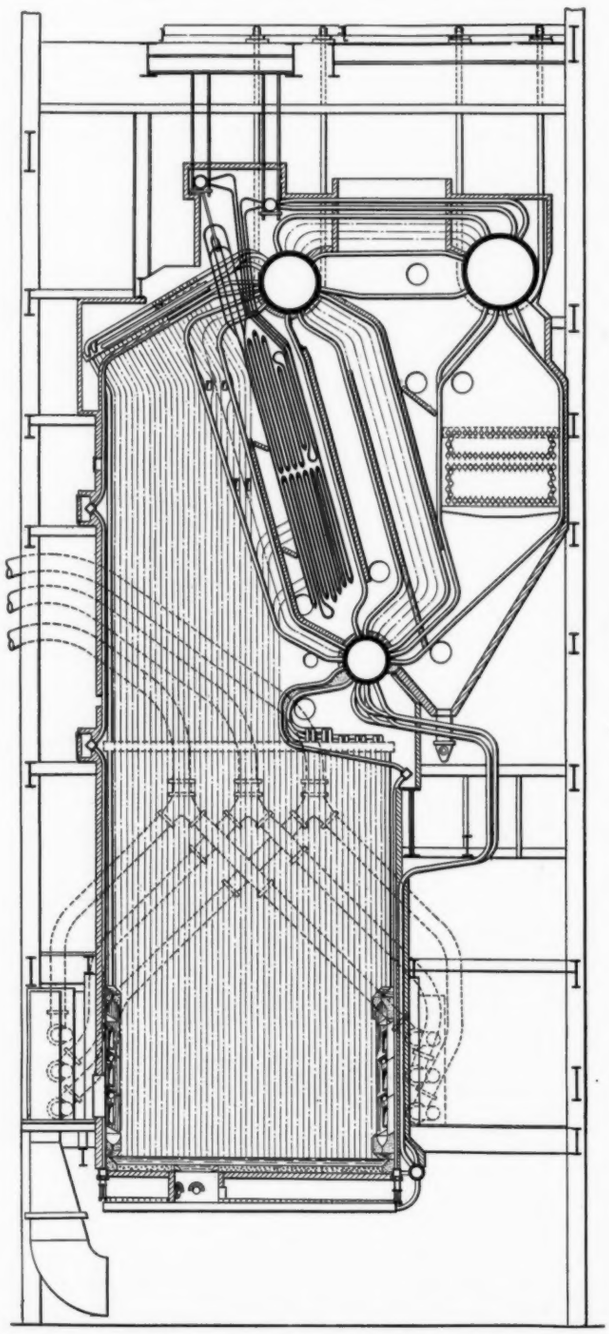


Fig. 6—Detailed section through boiler and furnace

The centrifugal boiler feed pumps are six-stage units. Two pumps operating in parallel will be capable of pumping 1,470,000 lb per hr against a total head of 1288 lb per sq in., each pump requiring 1830 hp. The boiler feed temperature will be approximately 390 F at all loads.

The centrifugal tank pumps are two-stage units. Two tank pumps operating in parallel will discharge 1,240,000

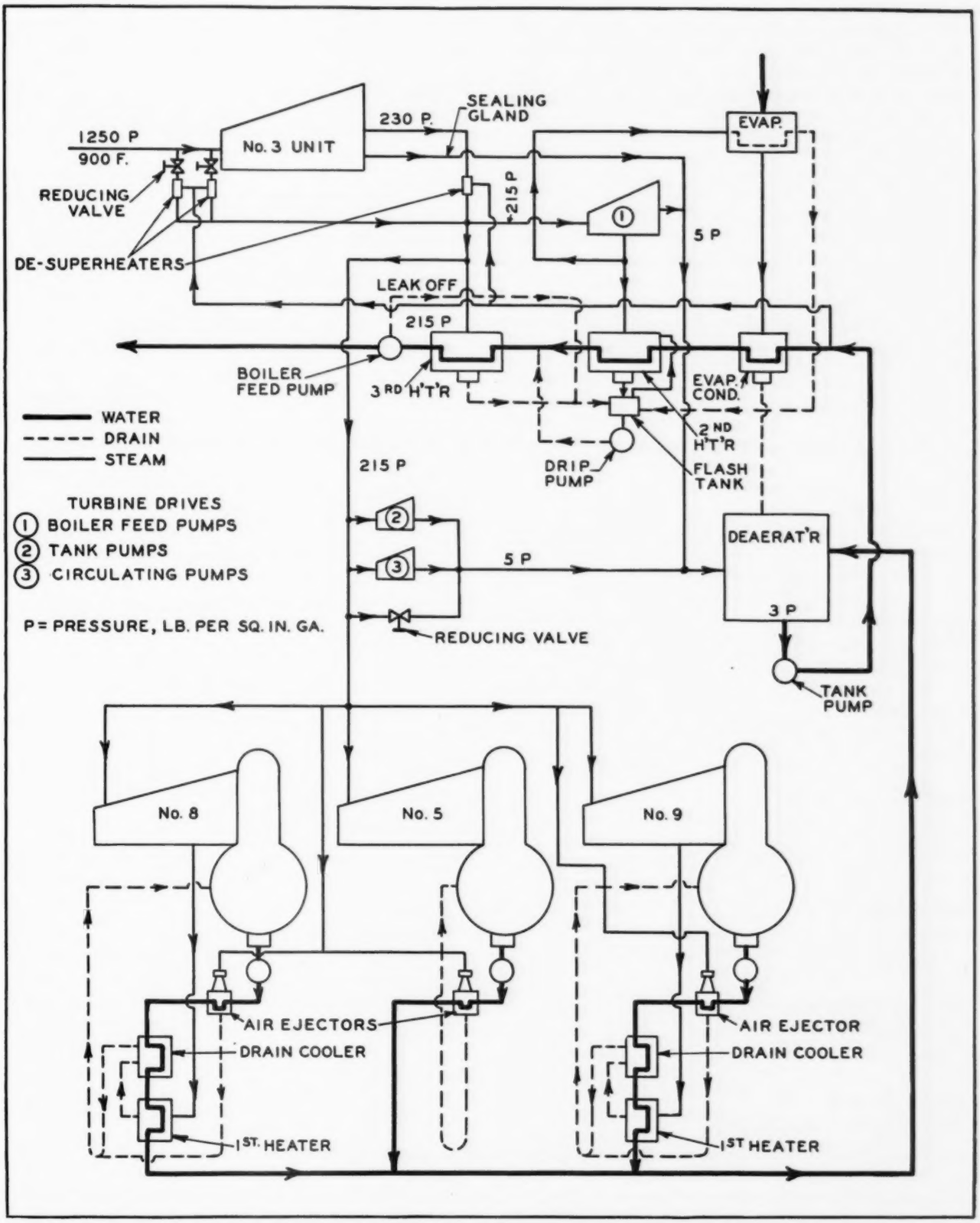


Fig. 7—The heat balance provides for turbine-driven boiler feed pumps, the turbines bleeding to the second heaters; low-pressure units Nos. 8 and 9 bleed to the first-stage heaters

lb per hr maximum of 220 F condensate, developing 410 lb per sq in. pressure, each pump requiring 390 hp.

Condensate from the main condensers passes successively through air ejectors, drain coolers, first heaters, deaerators, evaporator-condensers, second heaters and third heaters. Feedwater temperature entering the economizer will be 390 F. At full load the water temperature entering the boiler will be approximately 464 F. A duplicate set of heaters increases reliability and eliminates use of bypasses and valves that would be required

with a single set of feedwater heaters. Admiralty metal is being used on all heater tubes except the third high-pressure heaters which will have arsenical copper. Each set of heaters was designed for a load of 75 per cent of the high-pressure unit rating.

Existing circulating pumps are retained.

A reducing valve and desuperheating arrangement will allow added flexibility in the plant and permit operation of the low-pressure units during an outage of the high-pressure turbine. It will be possible through piping and desuperheating provisions to supply the vertical units, of which three remain, should load conditions warrant.

The Piping Specifications

The main steam piping will be of carbon-molybdenum steel, and valves of cast carbon-molybdenum will be welded in the line. Specification for the main steam piping is A.S.T.M.—A 158 Grade Pl and the schedule is No. 160—A.S.A.—B 36.10. Flanges and fittings where used will be 1500 lb A.S.A. Standard. Specification for boiler feed piping is A.S.T.M.—A 106 seamless open hearth, Grade B with the carbon content limited to 0.30.

Conclusion

This initial superposed capacity at Schuylkill Station has been so selected that in the future additional high efficiency capacity may be added in the existing building, should load and other conditions warrant it. Schuylkill Station with steam engine generators having an approximate heat consumption of 42,000 Btu per kwhr in 1903 has witnessed many advancements. Its 1937 contribution indicates an economy of about 11,800 Btu per kwhr.

Partial List of Equipment in High-Pressure Extension of Schuylkill Station

Boilers

Manufacturer	*Combustion Engineering Company, Inc.*
Number and Description	Two 600,000 lb per hr evaporation. 1350 lb per sq in. gage at superheater outlet—910 F with feedwater at 390 F. Heating surface 11,193 sq ft each. Three-drum bent tube with C-E water-cooled furnaces. Boiler arranged for pulverized coal firing.

Superheaters

Manufacturer	Elesco Superheater, *Superheater Company*
Number and Description	Two—To raise temperature of steam to 910 F at a pressure of 1350 lb per sq in. gage. Heating surface 16,300 sq ft each.

Economizers

Manufacturer	Elesco Economizer, *Combustion Engineering Company, Inc.*
Number and Description	Two—continuous loop economizer. Heating surface 11,500 sq ft each.

Pulverizers and Exhausters

Manufacturer	*Combustion Engineering Company, Inc.*
Number and Description	Raymond bowl No. 543. Six, three per boiler with integral exhauster. Capacity 30,000 lb per hr, each. Drive 250-hp, two-phase, 60-cycle, 1200-rpm motors, *General Electric Company.*

Air Preheaters

Manufacturer	Ljungstrom Air Preheater, *The Air Preheater Corporation*
Number and Description	Four, two per boiler—Type CGZX—No. 19.

Fans—Induced Draft

Manufacturer	*American Blower Corporation*
Number and Description	Four, two per boiler. With two fan operation 375,000 cfm, 23 in., 385 F.
Drive	1000-hp, two-phase, 60-cycle, 900-rpm, *General Electric Company* motors.

Fans—Forced Draft

Manufacturer	*American Blower Corporation*
Number and Description	Four, two per boiler. With two fan operation 205,000 cfm, 14 in., 95 F.
Drive	350-hp, two-phase, 60-cycle, 1200-rpm, *General Electric Company* motors.

Precipitators

Manufacturer	Cottrell Electrical Precipitation Equipment, *Research Corporation*
Number and Description	Two, each three units in parallel and two units long.

Turbine-Generator

Manufacturer	*Westinghouse Electric & Manufacturing Company*
Number and Description	One 50,000-kw 85 per cent pf (58,824 kva), 3600-rpm hydrogen-cooled, single-winding generator, 13,800 volts, 3-phase, 60-cycle, with 250-volt field and internal-ventilating fans. One 50,000-kw 3600-rpm combination impulse-reaction single-cylinder turbine designed for 1250-lb gage pressure, 900 F, 230-lb gage exhaust pressure.

Deaerating Heater

Manufacturer	*Cochrane Corporation*
Number and Description	Two units, horizontal cylindrical open-type each consisting of—two vent condensers, 540 sq ft each, one deaerating heater, rated 700,000 lb per hr zero oxygen, one storage tank, three minute capacity at 1,250,000 lb per hr.

Drain Color

Manufacturer	*Cochrane Corporation*
Number and Description	Two horizontal, straight-tube, one-piece floating-head type. Condensate side, four-pass around tubes. Drain side, single pass through tubes. 275 sq ft of surface. Rated capacity, 371,000 lb condensate, 25,900 lb drain, each.

No. 1 Heater

Manufacturer	*Cochrane Corporation*
Number and Description	Two vertical, straight-tube, four-pass one-piece. floating-head type, 2970 sq ft of surface. Rated capacity, 371,000 lb condensate each. Operating pressure 4 lb per sq in. abs.

Evaporator Condenser

Manufacturer	*Alco Products Company*
Number and Description	Two horizontal, two-pass floating-head type, 1810 sq ft of surface, each. Rated capacity 17,000 lb per hr vapor, at 29 lb per sq in. abs, each.

No. 2 Heaters

Manufacturer	*Alco Products Company*
Number and Description	Two vertical, two-pass floating-head type, 3300 sq ft of surface, each. Rated capacity, 680,000 lb water per hr each.

No. 3 Heaters

Manufacturer	*Alco Products Company*
Number and Description	Two vertical, two-pass floating-head type, 3820 sq ft of surface, each. Rated capacity, 845,000 lb per hr each.

Tank Pump Turbines

Manufacturer	*Elliott Company*
Number and Description	Three non-condensing, horizontal, four-stage, constant-speed, 3500 rpm, 390 hp, 215 lb gage, 517 F, 5 lb gage bp.

Boiler Feed Pump Turbines

Manufacturer	*Elliott Company*
Number and Description	Three non-condensing bleeder-type horizontal, six-stage, variable-speed, 2000 hp, 215 lb gage, 517 F, 5 lb gage bp. Non-controlled bleeder pressure.

Tank Pumps

Manufacturer	*Ingersoll-Rand Company*
Number and Description	Three centrifugal No. 4-GT, two-stage, 6 in. suction, 4 in. discharge, constant-speed, 3500 rpm, 1300-gpm, 410 lb per sq in. total head, 222 F water.

Boiler Feed Pumps

Manufacturer	*Ingersoll-Rand Company*
Number and Description	Three centrifugal No. 6-HT, six-stage, 10 in. suction, 6 in. discharge, variable-speed, 1700 gpm, 1288 lb per sq in. total head, 390 F water.

Boiler Baffling Arrangements

By W. S. PATTERSON
Combustion Engineering Company, Inc.

The various factors that influence the selection of baffling are reviewed; typical arrangements of longitudinal and cross-flow baffling for both straight-tube and bent-tube boilers of conventional design are shown and compared; and superheater location with reference to baffling is discussed.

THE proper selection and design of boiler baffles depends on many factors, such as: type of boiler, arrangement of tubes, desired location of gas outlet, type of superheater employed, method of controlling steam temperature, kind of fuel, method of firing, draft loss limitations, location of soot blowers, space available for access, repair and replacement, and probability of tube replacement. Finally, the baffles must be designed so as to facilitate maximum heat recovery from the hot gases consistent with a practical and economical draft loss.

The fewer the baffles used the better, provided they permit the heat transfer and arrangement of equipment desired. A boiler without any baffles would be ideal if the desired capacity, steam temperature and efficiency could be obtained at the same cost, including space occupied, etc., as the boiler having a more complicated baffle arrangement. In fact, a boiler without any baffles (single pass) is sometimes necessary in order to obtain a large steam capacity with very limited draft.

In any good baffle design, the number of sharp turns should be reduced to a minimum. A turn located within a space also occupied by tubes must be designed for a velocity consistent with the heat transfer rate desired from the heating surface. Turns which can be placed in the free space between banks of tubes do not have this limitation and may therefore be designed for lower velocity and consequent lower draft loss. The ideal baffle design would not, however, cause sudden contractions or enlargements of free gas passage area, because these changes in area result in loss of head in the gas stream. The ideal and the real are, however, two different stories, because few boilers are built that permit an "ideal" baffle arrangement; there are too many other practical considerations which govern the design.

Boiler baffle locations should not be fixed without first calculating all gas passage areas. What looks like a good arrangement and proportion might sometimes be improved. For example, Fig. 1 shows a semi-vertical bent-tube boiler arranged for three passes longitudinally baffled. To one not experienced in the proportioning of boiler baffles, the arrangement shown might be passed by as satisfactory. But consider the conditions existing at the lower edge of the second baffle. The tubes are $3^1/_4$-in. outside diameter. Their spacing averages 6 in. in width across the boiler, so that for every square foot of gross area under the edge of these baffles there is only 2.75 to 6.0, or 46 per cent as much net free gas passage area. It is not unusual to see a boiler, which has apparently been baffled by eye, with the linear distance from the lower edge of the second baffle to the drum shell equal to the depth of the preceding or following pass. Suppose that the depth spacing in the tube banks is 7 in., then in a longitudinal flow pass of a depth equal to the distance from the drum shell to the edge of the baffle the free area would be about 70 per cent greater. The restriction at the lower edge of the second baffle serves no good purpose but does, on the other hand, materially increase the draft loss.

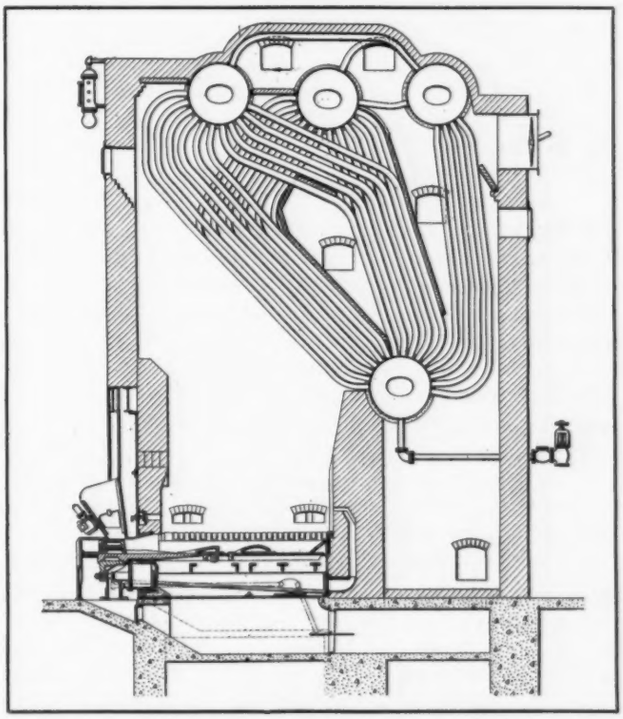


Fig. 1—Bent-tube boiler longitudinally baffled for three passes

The type of boiler very definitely limits the number of baffle arrangements that can be used, particularly when by "type" is meant such standard designs as straight-tube box or sectional header, or four-drum semi-vertical types. In the straight-tube type the furnace is generally placed under the boiler and the gas outlet is desired at the top. At once the number of passes for cross-flow baffling is established as an odd number, such as 1, 3 or 5. The first is seldom used, the second is the standard popular arrangement and the third is impractical with the tube lengths ordinarily encountered. The three-pass straight-tube boiler may be completely cross baffled with

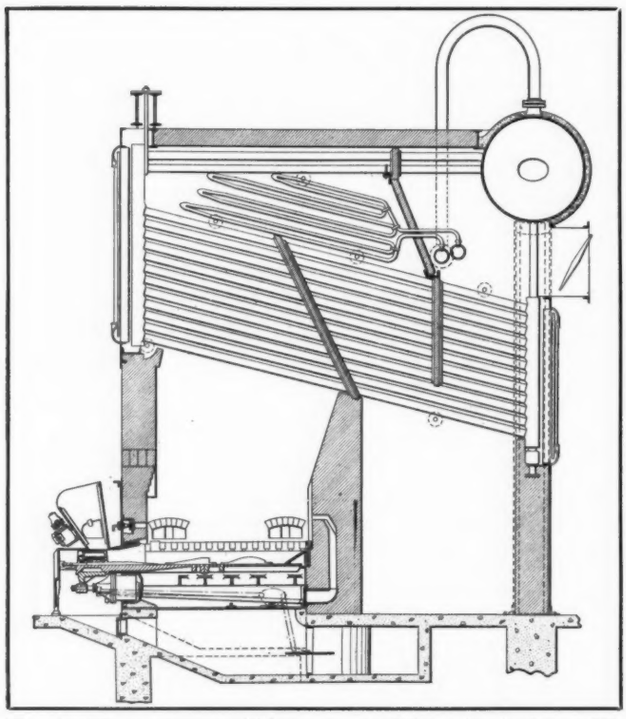


Fig. 2—Three-pass baffling on straight-tube boiler with first baffle starting at top of bridgewall

the first baffle starting at the top of a bridgewall, as illustrated by Fig. 2, or partly cross baffled with the so-called "combination" baffle employing a horizontal baffle in conjunction with the first cross baffle. The latter arrangement, as illustrated in Fig. 3, is common when a deeper furnace is required than would be possible with the bridgewall arrangement. The cross-flow baffles must be made of special shapes or of monolithic refractory construction, or a combination of both. They may or may not permit removal of the tubes without removing the baffle, depending on the condition of the tubes at the time of removal.

The use of horizontal baffles in a straight-tube boiler permits either an even or an odd number of passes, but the outlet must be at the top, whereas with an even number of cross passes the outlet can be arranged at the bottom as illustrated by Fig. 4. Horizontal baffles may be of standard flat tile, or of special shapes, depending on the tube arrangement. They are generally supported on the tube rows and therefore do not permit the independent removal of tubes on which they rest; see Fig. 5.

The four-drum bent-tube boiler has been growing in popularity. Since the tubes are nearly vertical, the use here of vertical baffles is equivalent in some respects to the application of horizontal baffles to a horizontal straight-tube boiler. However, since the four-drum boiler is V-shaped in design, because of the three upper drums and one lower drum, it is difficult to confine the gases strictly to the tube banks without placing baffles on both front and rear of all tube banks beyond the first. This means that baffles would have to be fastened to the underneath side of tubes, and would require more expensive construction and support as shown in Fig. 6. It is, therefore, customary in this type of boiler, to provide one vertical baffle per bank, supported on the upperside of the bank, and to attempt to keep the gases in contact with the tube surface by various arrangements of "kicker" baffles, so named because their purpose is to kick the gases back where they belong. When vertical baffles are used, they are generally of flat fireclay tile, supported at the bottom edge only, and so placed as to stay in position against the supporting row of tubes due to their own weight. However, this construction is generally modified when the boiler is to be fired with fuels burned in suspension, because of possible damage to the baffles which might result in the event of a furnace "puff." For such fuels it is always well to fasten the baffle to the supporting row of tubes, or to place it between two rows spaced so that baffle tile cannot be dislodged by a puff. A good arrangement of vertical baffles is therefore to place the first baffle between the first two rows of the second bank. This permits more uniform flow of gases across the front bank and in the case of hot slag-laden gases has proved effective in reducing the slag accumulation compared to the alternate arrangement of placing the first baffle on the last tube row of the first bank.

Bent-tube boilers may also be provided with cross-flow baffles of the three-pass design. For a complete cross-flow job the boiler outlet must be at the bottom of the rear bank or else an idle pass behind the rear bank, as shown in Fig. 7, must be used to provide a top outlet. With partial cross-flow baffling, employing one longitudinal flow pass at the back, as illustrated in Fig. 8, a top outlet may be obtained without sacrificing the floor space or cost of side wall extension required when the idle pass is used. However, if the entire rear bank is used for a vertical pass to provide a top outlet and the entire front bank is placed on the furnace side of the first baffle, such a design is far from being a cross-baffled boiler.

The majority of bent-tube boilers are designed so that individual tubes can be removed and replaced. If the cross-flow baffles are of solid monolithic construction, or

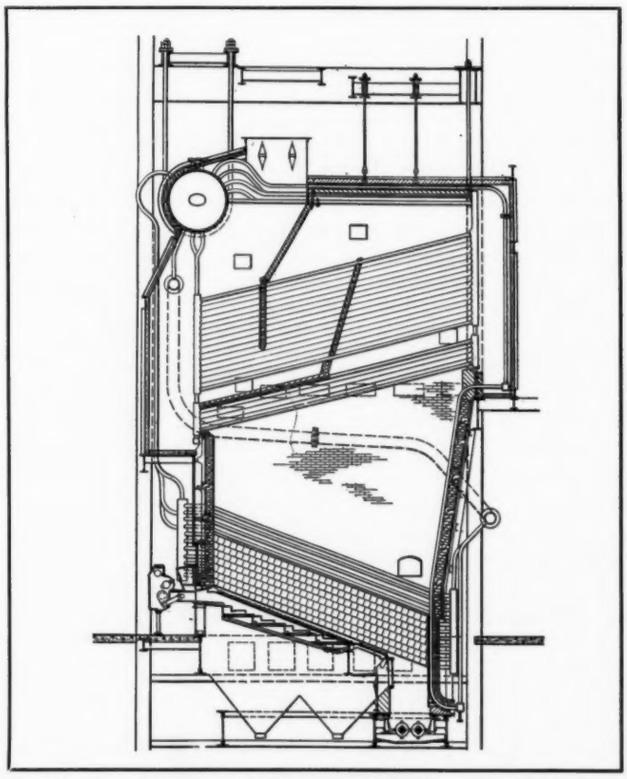


Fig. 3—Combination of horizontal baffle with first cross baffle as applied to a deep furnace

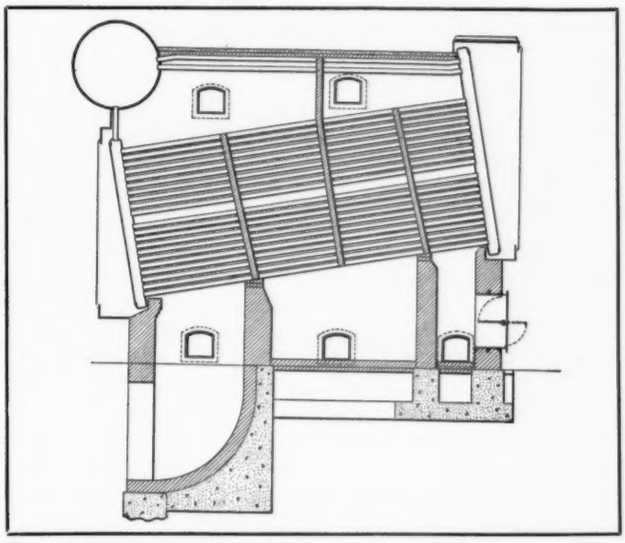


Fig. 4—Even number of passes with straight-tube boiler for bottom gas outlet

of the so-called "poured" construction, there is no simple way of replacing tubes. There are available, however, cross-flow baffles so designed that tube removal can be accomplished without extensive destruction of the baffles. It is problematical, however, whether any provision for tube removal is necessary and warranted in that portion of a bent-tube boiler beyond the first bank or, in other words, in that portion containing the baffles. The alternate wide and narrow spaces between tubes, ordinarily provided to permit tube removal, adversely affect the heat transfer as well as the cost of the boiler, and the use of cross baffles arranged to permit tube removal increases the cost of baffling.

The use of cross baffles in the conventional "V-type" boiler presents a problem of baffling in the last pass, regardless of the position of the boiler outlet opening, especially if the angle between the last baffle and a horizontal plane is very great. An angle of less than 20 deg ordinarily should not be used with coal firing. It is obvious then that in a deep boiler the rear tube connections to the lower drum will be well down on the rear side of the drum, and the inclined horizontal portion of the baffle will not produce a high uniform velocity or even gas distribution over this portion of the surface. The use of a curtain baffle of the filter type or a short solid baffle is sometimes resorted to in order that heat transfer in this zone may be improved.

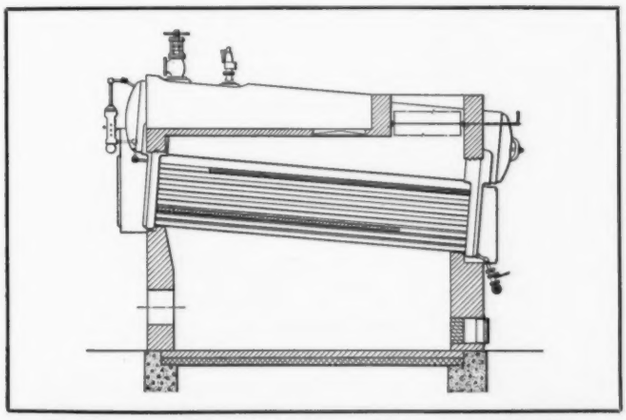


Fig. 5—Straight-tube boiler with horizontal baffles

The problem of baffling boilers of very special design, as furnished on large capacity high steam temperature jobs, is so closely related to the numerous factors governing the design of the individual steam generating unit that space does not permit its discussion here. It is, perhaps, sufficient to say that the design of these boilers and the design of the baffles that are to be used in them must be worked up together right from the very beginning, because in most cases controlled superheat is necessary and special baffle arrangements are used to accomplish this.

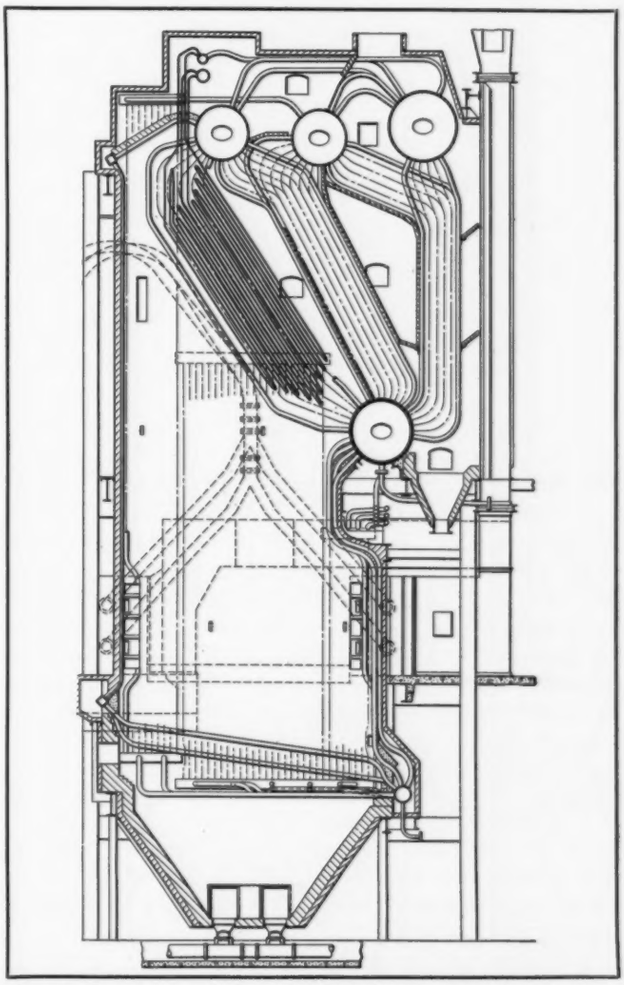


Fig. 6—Four-drum boiler with longitudinal baffles at front and rear of tube banks

This brings us to the point of discussing the effect of the superheater on the selection of the baffles. In the conventional straight-tube type of boiler, the use of a convection superheater at once limits the baffling to the cross-flow type. It is not common practice to install a convection superheater in a horizontally baffled straight-tube boiler. It may be said, however, that the particular type of superheater to be used imposes no other limitations on the method of baffling straight-tube boilers.

Superheaters, as applied to bent-tube boilers, may be placed between the tube rows of the front bank, or behind the front bank. With the former arrangement, the first boiler baffle is behind the superheater and the superheater is, therefore, exposed to radiant heat from the furnace. This results in a fairly flat superheat curve,

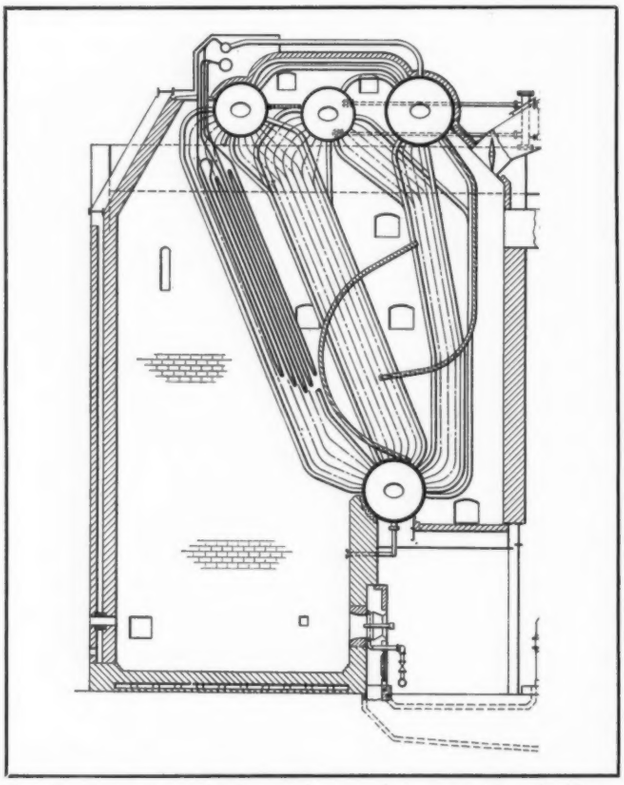


Fig. 7—Four-drum boiler with complete cross-flow baffling and idle pass for top gas outlet

which is desirable, but the baffling may not insure uniform gas flow over the superheater at all rates of operation, and with all furnace shapes and methods of firing. It is, therefore, difficult to predict accurately the steam temperature with this method of baffling, particularly when designing for a very high steam temperature. With the superheater arranged entirely behind the first bank it is generally confined to a separate pass of its own by means of a front and rear baffle; see Fig. 9. This eliminates the very desirable temperature leveling effect of exposure to radiant heat, but makes it possible to accurately calculate the gas velocity and heat transfer rate across the superheater. With this arrangement, therefore, it is necesary to provide means for obtaining a constant steam temperature through employment of a superheater bypass damper. The baffling is generally arranged so that the bypassed gases are mixed with the gases that have passed over the superheater before the latter come in contact with additional boiler heating surface. This requires an idle pass for the bypassed gases. It must be liberally proportioned or else the desired steam temperature control will not be obtained, because the diversion of the gases, in quantities up to as high as 50 per cent of the total, is obtained entirely due to difference in draft loss between the two gas circuits.

In bent-tube boilers having high superheated steam temperature requirements, it is necessary, therefore, to use vertical baffles in the front portion, in order to conveniently arrange the superheater and its control damper, but cross-flow horizontal baffles may be used in the rear.

The kind of fuel and the method of firing govern the number of possible baffle arrangements. As already mentioned, when a deep furnace is required under a straight-tube boiler, it is best obtained by exposing the entire length of the lower tube rows using the so-called combination baffles. Thus, when fuels are burned in suspension, such as in the case of solid fuel in pulverized form or liquids and gases, the bridgewall arrangement is generally not used although it may be used with certain types of stokers. Furthermore, considering the dust carried in the flue gases as a factor in baffle design, it is difficult to prevent accumulation of ash on horizontal baffles, particularly in zones of low velocity. It is true that if the velocity is so low as to allow ash to accumulate, any heating surface covered thereby is already somewhat ineffective, due to the low gas velocity. Better baffling will, however, eliminate the deposit and improve heat recovery. Furthermore, soot and ash allowed to remain in contact with metal surfaces during shutdown periods may have sufficient corrosive effect to be considered very definitely objectionable. On the other hand, the baffling of some boilers is purposely arranged to produce soot pockets where by change of directions and reduction in velocity a considerable portion of the solids carried can be deposited and removed continuously or at intervals to improve the heat recovery or to reduce dust nuisance.

Another consideration in baffle arrangement that is definitely related to the fuel burned is the initial entrance velocity to the boiler. Very hot gases containing ash in its molten or plastic state cannot be allowed to enter the boiler tube bank at excessive velocity if slag difficulties are to be avoided. High velocity results in impingement of the solids on the tube surface where it is solidified sufficiently to adhere and perhaps build up to the point of seriously choking up the gas passages. Lower entrance velocity permits the solids to follow the contours of the gas flow lanes and remain in suspension while the gases and ash are being cooled to the point where slag will not form. After this temperature is reached, the baffling can be arranged to produce higher velocity with the consequent benefits of better heat transfer.

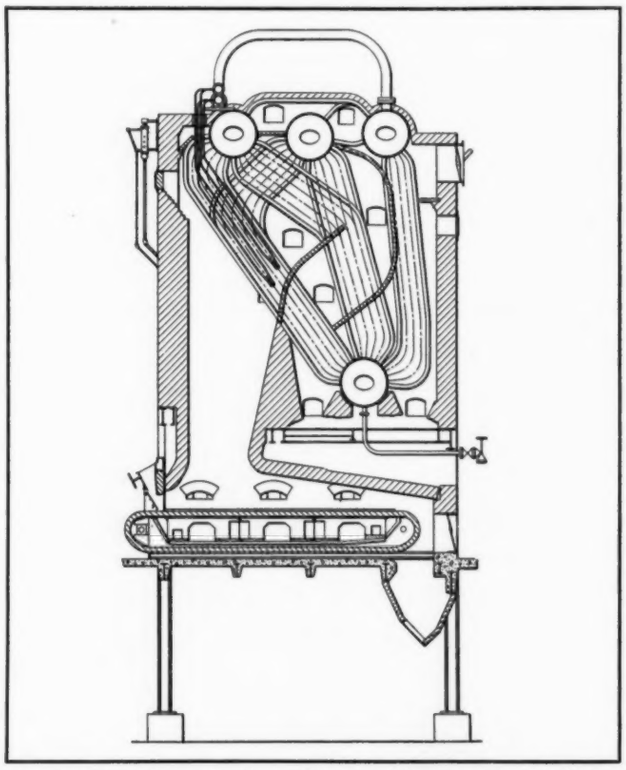


Fig. 8—Four-drum boiler with partial cross-flow baffling without idle pass for top gas outlet

The method of firing must also be considered in the arrangement of baffles. With traveling grate stokers, for example, the gases are actually baffled before they even enter the boiler. The popular use of a long rear arch over the grate as shown in Fig. 8 may be considered as nothing more than furnace baffling. One of its functions is to direct a stream of hot gases forward with sufficient velocity to penetrate the zone below the throat position, thereby aiding in igniting fresh coal and the combustion of distilled gases and CO in the zone below the throat. The throat position with respect to the boiler is also important, particularly when located below a vertical or semi-vertical boiler with a large portion of tube surface placed in front of the first boiler baffle. The gas velocity through the throat will be relatively high and the gases must be allowed a sufficient vertical distance in which to expand before reaching boiler tubes; otherwise there will be stratification in the first pass, higher entrance velocity than is apparent from a consideration of the boiler alone, poor heat recovery due to poor distribution of gases over the surface, and under certain conditions slag trouble due to high entrance velocity. Stratification in the first pass may also be caused by locating the throat too far forward or too far to the rear. The primary consideration as far as the boiler is concerned is to determine how the gases will expand above the throat and to locate the throat to give even distribution. This requires that the method of baffling be known in advance, or that the boiler baffling be designed to suit the previously fixed furnace arrangement. One cannot be set without consideration of the other.

To a certain extent the burner location for oil, gas or pulverized fuel influences the design and efficiency of the boiler baffles. Consider, for example, an oil- or gas-fired low-set straight-tube boiler. The position of the gas entrance to the boiler with respect to burner location is important. If the two are close together, part of the apparent furnace volume will not be used effectively and the time for combustion in the furnace is shortened. This will result in poorer performance than if the burner were located at the opposite end of the setting.

If the boiler manufacturer is to be held to guarantees on performance, he is entitled to have something to say about burner location and furnace design because on standard type boilers he cannot be expected to design special baffles to meet furnace design not suited to popular baffle arrangements. As previously mentioned, there are many other variables which govern the baffle arrangement most advantageously from a heat transfer, draft loss and cost point of view.

Draft loss limitations must very often be considered in boiler baffle design, particularly when no induced-draft fan is to be used. In general, it may be stated that after reducing the number of bends to a minimum and eliminating all restrictions and idle passes, no further reduction in draft loss can be obtained without a sacrifice in the efficiency of heat absorption. Further shortening of baffles to give a shorter minimum length of gas flow path will generally result in higher flue gas temperature, which will require more fuel to be burned for the same steam capacity, and more gas to be handled through the boiler, thus partly offsetting the apparent reduction in draft loss. The stack, however, will produce a greater draft due to increased temperature, so there is generally a net gain in steam output, but at a sacrifice of fuel consumption. It has not been conclusively proved that cross-flow baffles in every boiler will give a lower draft loss, at a given capacity, and without impaired efficiency, than properly designed longitudinal flow baffles. It can be shown by calculations based on test data that with some tube lengths and arrangements longitudinal flow baffles will produce better overall performance.

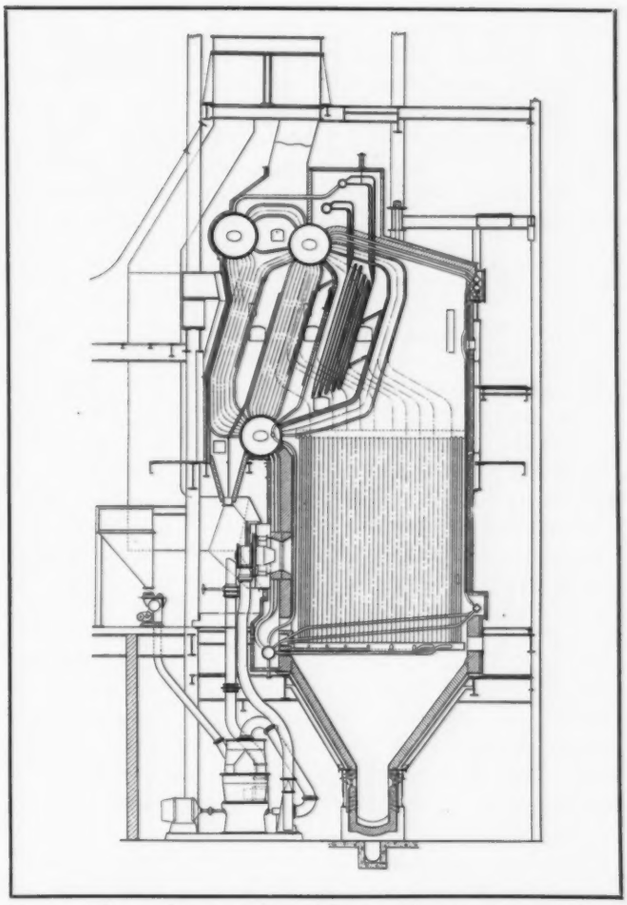


Fig. 9—Three-drum boiler with superheater located in a separate pass with a front and rear baffle

While strictly comparable test data may not always be available to indicate definitely whether a given boiler should be cross baffled or longitudinally baffled, consideration of the possible variations in boiler proportions indicate that there are limits which cannot be entirely ignored. For convenience let us consider a horizontal straight-tube boiler of a given furnace width, tube diameter, tube spacing and heating surface. Obviously, the exact proportions of the boiler are not fixed because tube length and the number of rows high may vary without affecting the heating surface in the tubes. With 20 ft long tubes the height of the bank will not be great, say, 10 rows (Case A), with tubes half as long, the height of bank will be 20 rows (Case B). Both boilers are to be baffled for three passes and both are to generate the same quantity of steam or, in other words, handle approximately the same quantity of gas. Case A cross baffled will have half the average gas velocity of Case B cross baffled, and about one-eighth the draft loss, but the flue gas temperature from Case A will be much higher. Now consider what would happen with the same two boilers baffled longitudinally, with horizontal baffles, placing the first baffle on the fourth row and the third

baffle on the top row. In Case A the second and third passes would be arranged three rows high each, with a maximum gas travel of 40 ft. In Case B the same passes would be arranged eight rows each, or nine and seven producing less than 40 per cent of the average velocity and a maximum gas travel in the two passes of 20 ft. Even allowing for the better heat transfer with cross flow compared to longitudinal flow at a given gas velocity, the Case A boiler would give higher efficiency if provided with horizontal baffles. Case B naturally would benefit by use of cross baffles.

Similar comparisons could be drawn between bent-tube boilers of various proportions to show that a boiler with a shallow tube depth, but great distance between drums, will give better heat absorption when vertically baffled than cross baffled. Conversely, a boiler having many more rows deep, but shorter tubes aggregating the same tube surface, will give better heat absorption when cross baffled than when vertically baffled. In the case of bent-tube boilers, the tubes are generally arranged in unstaggered rows. With this arrangement, less improvement in heat transfer is to be expected with cross flow compared to longitudinal flow than would be expected with tubes in staggered relationship. Improved heat transfer in either case is not obtained without a sacrifice of draft loss, but the cross flow velocity can be reduced to a lower value on a staggered tube boiler than on one with tubes in alignment without loss in efficiency.

A. S. M. E. Nominations

Nominations for officers of The American Society of Mechanical Engineers for 1938 were announced at a meeting of the Nominating Committee held at Detroit, Mich., during the recent Semi-Annual Meeting. Election will be held by letter ballot of the entire membership, closing on September 28, 1937. The nominees as presented by the Nominating Committee are:

President	Harvey N. Davis, President, Stevens Inst. of Technology, Hoboken, N. J.
Vice-Presidents (To serve 1 year)	F. O. Hoagland, Master Mechanic, Pratt & Whitney Division, Niles Bement-Pond Company, Hartford, Conn.
(To serve 2 years)	B. M. Brigman, Dean, Speed Scientific School, University of Louisville, Louisville, Ky.
	Harte Cooke, Mechanical Engineer, McIntosh & Seymour Corporation, Auburn, N. Y.
	W. H. McBryde, Consulting Engineer, 1111 Financial Center Bldg., San Francisco, Calif.
	L. W. Wallace, Director of Equipment Research, Association of American Railroads, Chicago, Ill.
Managers (To serve 3 years)	Carl Bausch, Vice-President, Bausch & Lomb Optical Company, Rochester, N. Y.
	S. B. Earle, Dean, School of Engineering, Clemson A. & M. College, Clemson College, S. C.
	F. H. Prouty, Denver, Colo.

Settling of Smoke by Use of Whistle

A demonstration of the settling of fumes and smoke by the use of a whistle producing sound waves of extremely high frequency was given at the Air Pollution Show, sponsored by the Smoke Abatement Association at the Hotel Pennsylvania, New York, on May 31 to June 5. The device, developed by the U. S. Bureau of Mines, has attracted wide attention.

Kundt discovered in 1866 that, when sound waves are passed through a tube containing a fine powder, the powder is concentrated at points that are free from vibratory motion. Such Kundt figures are shown by the arrangement of cork dust in a glass tube, in which there are standing waves of about 3000 to 6000 cycles per second frequency. It has also been known that waves of extremely high frequency affected the diffusion of solid or liquid particles in a gas. However, no practical application was made of these phenomena to the smoke problem until the metallurgical staff of the Bureau of Mines applied them to the treatment of smelter fumes. This organization is pushing forward the development of apparatus for this purpose which may also be applicable in general smoke and dust abatement.

The new method merely passes the smoke or fumes through a tube in which standing sound waves are established. These standing waves are produced by so adjusting the length of the tube that waves reflected from the upper end are in phase with the original sound waves set up at the lower end.

In order that the process may work at its best, the wave length used must be approximately equal to the diameter of the tube. For a tube of practicable diameter, this means that the frequencies used will vary from 3000 to 20,000 cycles per second. A person of acute hearing can distinguish tones of frequencies up to about 5000. Vibrations of a frequency greater than about 16,000 cycles per second are above the audible range and hence are sometimes called "ultrasonic" or "supersonic."

To generate sound waves of the proper frequency, several types of equipment have been used. The demonstration at the Air Pollution Show uses both the so-called magnetostrictive generator and the acoustic air-jet generator of Hartmann. The magnetostrictive generator depends on the change in length of a magnetic material (nickel in this case) in a magnetic field, the alternating field being produced by a radio-tube oscillator; the Hartmann generator is simply a shrill whistle of special design. The sound waves produced by either generator are reflected at the top of a closed glass tube to be in phase with the original wave, thus setting up standing waves of pressure change separated by planes of no motion—the nodes—spaced half a wave length (about $1^1/_2$ in.) apart. The coagulation of the suspended particles is brought about by collisions between these particles in their complicated movements between nodes, and the heavier flocculated masses finally collect at the points of no motion—the nodes. The action is similar to the effect produced by drawing the bow of a violin over a metal plate on which dust particles are deposited when the vibrations of the plate cause the particles to migrate to the nodes and thus arrange themselves in patterns.

Patents covering the new process will be applied for by members of the Metallurgical Staff of the Bureau of Mines for the benefit of the public.

Boiler Inspectors Meet at New York

A review of the high spots of some of the papers dealing with the A. S. M. E. Boiler Code changes, forced-circulation boilers, the design and operation of large high-pressure steam-generating units, the prevention of furnace explosions and various aspects of welding pressure vessels and of welding alloy steels.

ONE of the most successful Annual Meetings of the National Board of Boiler and Pressure Vessel Inspectors was held at the Hotel McAlpin, New York, from May 24 to 27. The attendance was large and an attractive program of technical papers on welding and numerous boiler problems, supplemented by an exhibit by the insurance companies and boiler manufacturers served to render the meeting very instructive. There were also visits to Waterside Station, where new high-pressure boilers are being installed, and to the plant of the M. W. Kellogg Company, where the fabrication of welded pressure vessels and the welding of piping was observed. Of the eighteen technical papers presented space here permits reviewing only the high spots of a few. The papers will all appear in full in the Transactions of the National Board.

Boiler Code Proposals and Welding Research

Dr. D. S. Jacobus, as past president of the American Welding Society and as chairman of the A. S. M. E. Boiler Code Committee, spoke of the cooperation of these two bodies with the National Board of Boiler and Pressure Vessel Inspectors. Reviewing recent activities of the Boiler Code Committee he said that it is proposed to establish one set of rules for the qualification of welding processes and a second set for the testing of welding operators based on those prepared by the American Welding Society.

A new standard set of radiographic films has been adopted which will limit the porosity of the weld metal to a greater degree than the previous standard films.

The stamping provisions in the Code have been revised to provide that in addition to boilers the Code symbol will be applied to superheaters, water walls and steaming economizers.

A new basis has been agreed upon for determining the minimum safety valve capacity to be installed.

New rules have been prepared to cover the fusion welding of piping used in connection with boilers and other features of welding not previously covered in the Code.

A careful investigation has been made of the use of the higher tensile strength steel covered by Specification S-26 for U-69 vessels and an agreement reached with all those representing the industry. Also, active work is now being carried out on revision of the Unfired Pressure Vessel Code, the allowable stresses for ferrous materials at different operating temperatures, the allowable stresses for non-ferrous materials, a revision of the tube tables, special designs to meet increasing steam pressures in large boiler drum construction and rules to cover clad vessels.

Speaking for the Welding Society, Dr. Jacobus mentioned that its Research Committee has had placed at its disposal by the Engineering Foundation the sum of $5000 a year and a second appropriation of the same amount contingent upon contributions from industry of a sum sufficient to enable the Committee to carry out its research program. Upward of $20,000 has already been collected from industry for the work of the present year.

Forced-Circulation Boilers

H. B. Oatley discussed, generally, the circulation in boilers and pointed out the essential differences between boilers of the "once-through" type, those with assisted circulation, those having forced circulation with a circulating pump and those employing forced circulation without such a pump. Certain well-known boilers, mostly European, were identified as falling within these classifications.

Fig. 1 represents, diagrammatically, a once-through type. This has a feed pump which delivers water into one end of a long tube from the opposite end of which steam is delivered. Multiple parallel circuits may be employed instead of a single tube. Generally, boilers of this type have small diameter tubing, coiled into helical form. Because of the high resistance to flow through a single tube a single-circuit boiler of this type delivering steam at 1400 lb would require a feed pump pressure of 1850 lb. As there are no drums, there is no appreciable heat storage in the water, hence a very rapid and sensitive response to steam demand is required both for the feed pump and the fuel supply. In the section of the tube where conversion of water into steam occurs impurities are precipitated as scale or sludge, hence in the more recent boilers of this type (see Fig. 1a) this conversion zone has been located in a region of lower gas temperatures and in some designs the path of the water and steam in this section has been enlarged so as to decrease the velocity and make provision for cleaning or removal without disturbing other parts of the boiler. The author pointed out, however, that despite such provisions, solids in the water may pass in large proportion directly to the prime mover, hence pure feedwater is necessary. Once-

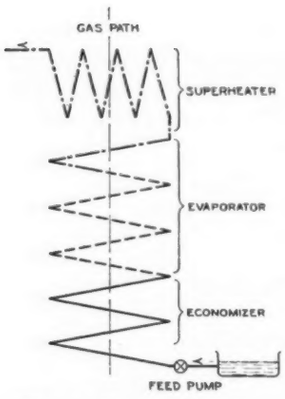


Fig. 1—Once-through boiler of early design

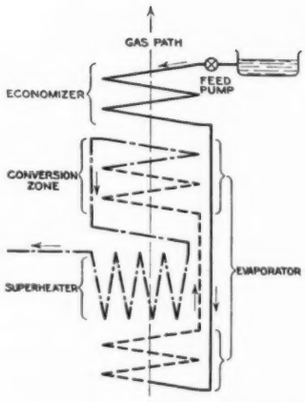


Fig. 1a—Once-through boiler of latest design

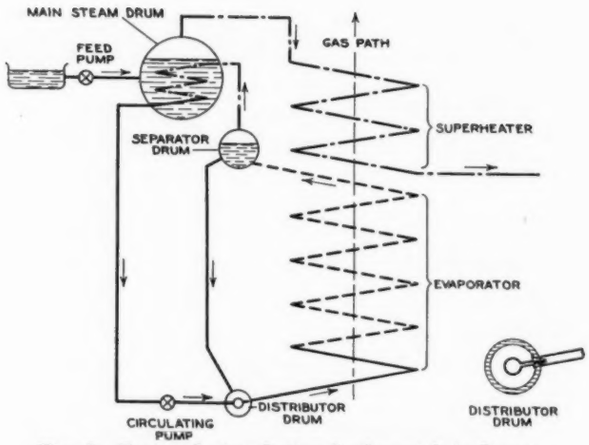


Fig. 2—Assisted-circulation boiler with indirect steam generation

through boilers which have been used to a greater or lesser extent are the Doble (now termed the Besler), the Benson, the Sulzer and one B & W design.

Fig. 2 represents a boiler with "assisted circulation" the object of which is to provide, by means of a separate pump, a forced circulation which will exceed that which would normally occur.

The forced-circulation boiler, having a circulating pump is represented diagrammatically by Fig. 3. Included in this group are the Ryan, the La Mont, the Velox and (with one point of difference) the Loeffler. In the last named type the circulating medium is steam; see Fig. 3a. In both the Velox and the La Mont boilers a much larger quantity of water is circulated than is converted into steam, the former circulating approximately twice and the La Mont eight times the amount of steam, although these ratios can be varied within wide limits. The amount of power required by the circulating pump must, of course, be included in the power requirements for operation, but this is not large as the suction of the pump carries boiler pressure and the pump has to operate against only 30 to 40 lb head. In the Loeffler boiler, however, the delivery pressure is 50 to 60 lb above the working pressure of the boiler and a greater weight of steam is circulated than is delivered to the prime mover.

In such designs the water or steam velocities through the tubes which are subjected to the highest gas temperatures are higher than with natural circulation and therefore provide greater protection to the tubes. Also, high water velocities minimize the possibility of scale accumulation. Compared with the once-through boiler, there is an opportunity for removing solid matter by blowing down from the bottom of the collector drum. The Velox boiler differs from the other boilers in this group in that combustion takes place in the furnace at 20 to 35 lb per sq in. with resulting high gas velocities and consequent high rates of heat transfer.

Fig. 4 represents the "spill-over" type of boiler, without a circulating pump as brought out jointly by the Babcock & Wilcox Company, the General Electric Company and the Bailey Meter Company, primarily for locomotive use. The feed pump forces water through tube coils from which a steam-and-water mixture is delivered to a separator drum. The steam passes from the drum through the superheater to the point of use and the water spill-over escapes through a pressure-reducing resistance and feedwater heater to the suction of the feed pump. In this design the amount of water fed through the heat-absorbing coils exceeds the maximum evaporation only by about 10 per cent, whereas boilers with a separate circulating pump have an excess of 700 to 1500

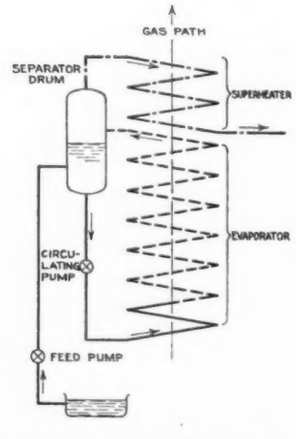


Fig. 3—Forced-circulation boiler with circulating pump

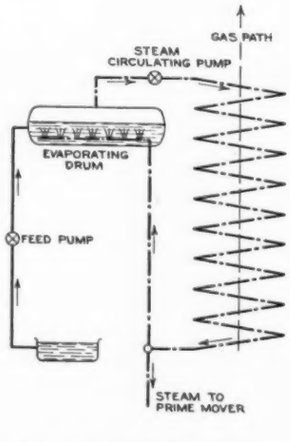


Fig. 3a—Boiler with steam circulating pump

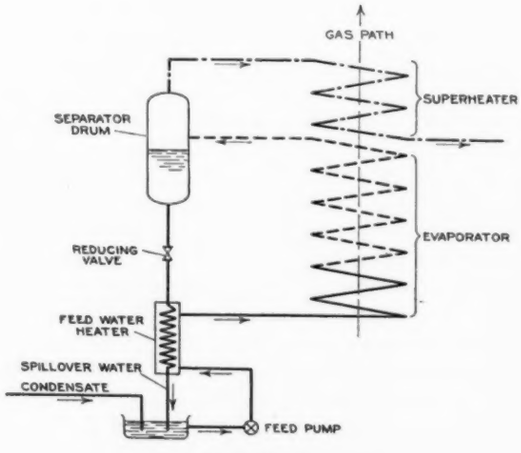


Fig. 4—Spill-over type of boiler

per cent. The claims made for the La Mont boiler can be properly applied to this "spill-over" type.

In practically all the designs discussed it has been found necessary to provide a plurality of tubes in parallel and both the La Mont and the B & W designs employ restricted inlets to the parallel circuits, the pressure difference between the pump and these orifices assuring a more nearly equal distribution.

The small water storage capacity of forced-circulation and once-through boilers, as compared with natural-circulation boilers with drums, requires a maximum of perfection in the control devices for feedwater, steam temperature and steam pressure.

In conclusion, Mr. Oatley offered, in substance, the following observations on these types of boilers:

1. In starting, the forced-flow (once-through) boiler requires an outside source of power and the steam circulating type (Loeffler) also requires an outside supply of steam.

2. More steam can be produced per pound of boiler weight and per cubic foot of boiler volume—a consideration in marine and locomotive installations.

3. The material and labor cost involved in these designs per pound of steam developed is not particularly attractive at the present time as compared with natural-circulation boilers, although as more experience is gained development costs and other than real production costs will form a smaller percentage of the selling price. Material and labor cost should ultimately be lower than with natural-circulation boilers except for the more complicated control apparatus required.

4. From data now available it appears that the total power required for a given output of steam is highest in the forced-circulation boiler where steam is circulated, with the more commonly used forced-circulation boiler ranging next, the once-through type next and the natural-circulation boiler lowest. However, this may change somewhat as certain modifications are being tried and the circulating pump is being studied with a view to improvement in efficiency.

Developments in Steam Generating Units

John Van Brunt, in discussing developments in the design and construction of boilers for high and intermediate pressures, reviewed the trend toward larger capacity units employing both high pressures and high steam temperatures, and some of the problems involved in reconciling and correlating all the factors of pressure, steam temperature, feedwater temperature, ash fusion temperature, etc.; all of which call for very close design in order that predicted figures and performance may be met. Twenty years ago there were few boilers that developed over 5000 lb of steam per hr per ft of width, whereas today 20,000 lb per ft of width is not unusual and a few are producing 25,000 lb per ft of width.

Comparing some of the earlier high-pressure units with those of recent design he called attention to the marked redistribution of heat-absorbing surface for a given output. In some of the units now under construction the boiler heating surface proper accounts for less than 7 per cent of the total, the remaining surface being made up by the water walls, superheater, air heater and economizer.

A number of slides of recent units were shown and their individual features discussed. A table was presented giving data on 100 recent high- and intermediate-pressure steam generating units constructed by the author's company which was highly indicative of present trends. Of these 100 units, 90 were of the multi-drum bent-tube design and 10 of the straight-tube type. Twenty-three were for pressures over 1200 lb and 21 employed temperatures over 900 F. Pulverized coal firing was employed on 70 of the units, 10 of which had slagging bottom furnaces and the remainder dry bottom. Economizers were employed on 47 and air heaters on 86; both economizers and air heaters being used on 39.

With the acceptance of fusion welded boiler drums by the A. S. M. E. Boiler Code the cost of multi-drum boilers may be reduced to a figure which compares favorably with that of single-drum boilers. Other factors which have made possible further reductions in cost are the large capacity units possible only with pulverized coal firing, the use of complete water cooling of furnace walls and improved water treatment which permits the use of the continuous-tube economizer. Also, high steam temperature renders unnecessary any considerable amount of boiler surface following the superheater, hence the spacing between the boiler tubes may be greater, which in turn permits the use of thinner and less costly drum plate.

Commenting further on the predominance of bent-tube units as shown by the table, Mr. Van Brunt expressed the belief that this ratio would be retained, approximately, for high-pressure boilers, as time goes on. This opinion he substantiated by pointing out that this type is relatively free from expansion strains resulting from the temperature of the heavy wall tubes, because the bent tubes deflect enough to relieve the rolled joints from strain; also, the circulation is unrestricted so that there is ample water in each tube to insure adequate cooling.

Because of the many and varying factors entering into the design of large high-pressure steam generating units, it has not been, nor is it yet, possible to reach a standard design. It has been approached to a limited extent in the wide adoption of the three-drum boiler with economizer located between two rows of tubes that connect the upper rear and the lower drums. However, because variations in coal and in steam temperature requirements affect the relation of furnace volume to boiler surface, only a partial standardization of drum sizes and tube arrangements appears possible.

Operation of Large Modern Steam Generating Units

E. H. Krieg linked operating problems to the primary function of a steam generating unit, namely, to produce the proper quantity and quality of steam as economically as possible. In this connection, reliability, or availability, is a most important factor affecting the carrying charges on the investment.

Boiler availability has been greatly improved in recent years until it now equals turbine availability. It has therefore become possible to schedule boiler outages with the same regularity as turbine outages. With a boiler designed for such availability there appears to be little economic justification for the extra cost of a multiple boiler plant on an interconnected system where the

necessary safeguards exist. Old-time plants always had one or more spare boilers because it was commonly accepted that boilers could not operate more than a month or two continuously, whereas now plants are being installed and operated successfully with a single boiler per turbine.

At Lakeside boiler availabilities of 94.7 per cent for 1934, 98.1 per cent for 1933 and 97.1 per cent for 1932 were reported. Based on the experience of the American Gas and Electric Company it was the author's opinion that better than 90 per cent availability can be attained regularly on 1400 lb boilers.

Of course, in some cases it may be cheaper to install several boilers rather than one large boiler in order to use an existing building which otherwise would require extensive alterations in order to house a single large boiler.

Mr. Krieg stated that while there were no particular difficulties encountered in the operation of large modern steam generating units, there were certain problems which must be given consideration in advance. For instance, in order to avoid outages caused by slagging of the tubes it is desirable when designing such a unit first to plot the fusion temperatures of the available coals and the temperature of the furnace gases entering the slag screen or superheater, for the anticipated operating conditions, in order to be assured that troublesome slagging will not occur.

Sometimes cinder troubles are met with in the induced-draft fans and for this reason it is usually best to install two fans of such capacity so that if one is out the other will carry the boiler up to 75 per cent capacity.

Choice of Furnace Bottoms

As to getting rid of the ash in large units, the choice between a wet or a dry bottom furnace depends upon the loading of the unit and the fusion temperature of the ash. With a coal of relatively low ash-fusion temperature and a fairly steady load the slagging bottom furnace provides a solution to the ash disposal problem, but with a coa of high ash-fusion temperature and wide load swings, particularly sustained light loads, the dry bottom furnace will give less trouble. Moreover, it has somewhat greater flexibility.

Mr. Krieg compared the situations at the Logan and Windsor Stations. At the former, one large unit of the dry-bottom type is being installed. Here the coal has a higher ash-fusion temperature and the load range is broader, whereas at Windsor a somewhat different loading condition exists and the coal may have a lower ash-fusion temperature. In this case two steam generating units were installed, one with a dry bottom and one with a slagging bottom.

No difficulties have been encountered in maintaining water level in high-pressure units, but they should be equipped with level recorders, because indicators do not always show the true level. Stratification of the gases will cause different levels in different parts of the drum.

As to boiler feed pumps, two turbine-driven pumps will seldom operate satisfactorily in parallel unless means are taken to regulate pump speed to obtain equal amounts of water from each pump. Pressure regulation alone is not adequate.

Tube starvation, scale deposits and trouble from flame impingement have now been licked by the boiler designers and mechanical deaeration is now doing pretty well. There is no longer much trouble from carry-over and the return-bend economizer has effectively eliminated economizer gasket leaks.

Touching upon the subject of corrosion, Mr. Krieg mentioned one 1400 lb plant that had experienced tube corrosion at an amazingly rapid rate. Tests of the boiler water failed to reveal the presence of oxygen but further investigation indicated that the chemical deaeration employed had apparently set up electrochemical or electrolytic action, for all corrosion ceased when the chemical oxygen-reducing agent was discontinued.

Prevention of Furnace Explosions

E. G. Bailey, in a paper discussing this subject, pointed out that no furnace and no kind of fuel is immune from some possible explosion hazard, despite all the attention that has been given it. In view of this, it is best when such an explosion does occur to investigate it thoroughly and give publicity to the facts so that they may serve as a guide to those responsible for the design, inspection and operation of such equipment.

The greatest number of furnace explosions occur when starting up or lighting off, particularly with gas and pulverized coal. Another condition that may lead to an explosion is a stopping or decrease in fuel feed, causing loss of ignition and then a resumption of fuel without repeating the proper lighting cycle. While a refractory furnace may retain sufficient heat for a short time to reignite the fuel, a delayed ignition is hazardous. In every case the fuel should be shut off and relighted in the regular way.

Still another condition that may result in an explosion is a decrease in the air supply to an extent that unburned fuel accumulates in the furnace and flues which may ignite when the proper fuel-air ratio is restored or if there be abnormal excess air.

To safeguard against explosions in lighting off, Mr. Bailey recommended the following precautions:

1. Purge the furnace of all fuel.
2. Apply an ample torch flame to each burner, in succession, before the fuel is turned on.
3. Keep the air velocity low enough to prevent blowing out the flame.
4. Supply a sufficiently rich mixture of fuel to immediately ignite from the torch. This is similar to using the choke when starting an automobile. If the coal is not rich enough to ignite in a reasonable time the operator should cut off the coal feed, also the torch; scavenge the furnace and try again.
5. After ignition is established, the correct proportion of fuel and air should be maintained and the furnace operated at a high enough rate to maintain stable ignition.
6. Emergencies caused by power failure, fuel failure, wet coal, water in oil, etc., must be provided for and the fans, feeders and fuel supply should be started in proper sequence. Moreover, they should be properly interlocked. Adequate instruments should be installed so that the operator will know exactly what is taking place and the operation of fans, dampers and fuel supply should be controllable from an accessible place on the operating floor.
7. It is never safe to light off gas, oil or pulverized coal without first scavenging the furnace for five minutes.

8. Oil torches burning No. 3 furnace oil at the rate of 260 to 300 lb per hr are ample and gas torches should give a luminous flame of 4 to 8 ft long. Ignition should start within 5 sec—not more than 10 sec—and the flame should be stable within 30 to 40 sec.

After stable ignition has been obtained the torches should be cut off and the fuel-air ratio properly maintained. A failure of air supply for combustion should immediately shut off the fuel, but a failure of the fuel supply or loss of ignition need not cut off the air supply.

A short interruption of fuel and then a resumption with delayed ignition is one of the greatest hazards with any fuel. Pulverized coal or oil entering a furnace which is hot, but below the ignition temperature, may produce a hazard by distilling gas and diffusing it more evenly throughout the furnace than would either the coal in pulverized form or oil in atomized form. For this reason lighting torches should be cut off as soon as sustained ignition is attained.

With reference to explosion doors, Mr. Bailey expressed the opinion that they are inadequate to protect against a heavy explosion and not necessary for a slight puff or light explosion; hence they are of benefit only for the intermediate cases. Moreover, water-cooled furnaces have a tendency to minimize explosions as they cool the furnace quickly after loss of ignition and even if there should be a puff the lower temperature will narrow the explosion range.

Finally, with reference to accumulations of dust in settings and flues, such material should be blown out while the boiler is operating and the gases going through the boiler and flues with a low percentage of oxygen. After the boiler has been shut down if some fire is smoldering in such localities and the soot blower is turned on, the stirring up of the combustible dust may cause an explosion.

Maintaining High Standards for Welded Vessels

A. C. Weigel placed the human element as one of the most important factors in the maintenance of a high standard of welding work. Regardless of the supervision employed, the percentage of welders that can be absolutely depended upon at all times is small. But the knowledge that the quality of a man's work is to be checked by X-ray examination, as is done in Class I welding, is likely to make him more careful. The mere fact that the best equipped shops are unable to consistently turn out work without discovering faults by mean of X-ray examination emphasizes the risk involved in much work turned out by less experienced and less completely equipped shops that do not employ the X-ray to determine the existence of hidden defects.

In support of this, Mr. Weigel cited the experience of The Hartford Steam Boiler Inspection and Insurance Company in examining a large number of trepanned plugs cut from Class II welded pressure vessels, none of which showed a perfect weld. He further showed a number of slides, borrowed from that company, showing failures in Class II pressure vessels, with various degrees of damage, that had resulted from improper welding.

The deduction from these and many similar cases is that all pressure vessels subjected to severe service or to corrosion should be X-rayed and stress-relieved; or those that are not should have extra care exercised in their fabrication.

"Slag inclusions, lack of fusion and cracks are among the most dangerous defects in a weld," said Mr. Weigel, "and it is important that locked-up stresses be relieved, as they not only may lead to ultimate failure but they also accelerate corrosion. Attention to the possibility of such stresses should be given in the design of the vessel."

In the days of riveted vessels, material was purchased on the mills' analyses and certain chemical properties and defects, such as slag inclusions and slight laminations were not so important; but with the coming of welded construction these assume greater importance as they will cause trouble.

Even though all prescribed mill tests are made and the material is further tested by bending cold to form the shell there may be chemical segregations. A plate averaging 0.30 carbon may, in a small area, contain as high as 0.40 carbon, and even much higher. Also sulphur and phosphorus, both enemies of welding, segregate to cause trouble. Impurities such as arsenic, tin, lead, etc., may exist to a dangerous degree due to the use of a high percentage of scrap by the mills.

In conclusion, the author stated that while the paper had called attention to faults that can exist and must be carefully watched for, he did not wish it to be inferred that with proper care and precision in properly regulated fabricating plants that good and reliable welds could not be produced.

Welding High Tensile Strength, Low Alloy Steels

Dr. J. C. Hodge, in his talk on this subject, explained that low alloy, high tensile strength steels is a term applied to a group of steels of variable chemical composition used principally in structural fabrication; that is, they are employed for static rather than dynamic loading. They have a tensile strength of 70,000 to 100,000 lb per sq in. and cold working or heat-treating is impracticable for very large structures or vessels. They must have enough ductility to withstand bending and rolling, and must be free from air-hardening or weld-hardening characteristics. The alloying elements range up to 2½ per cent.

Chromium-molybdenum steels are especially adapted to use in superheaters and in the transportation field but otherwise are little used for pressure vessels.

Three alloy steels suitable for welded pressure vessels were noted. One is 2½ per cent nickel steel for low-temperature use. Another is chromium-molybdenum steel (0.5 Mo) for welded pressure vessels to give increased creep resistance at higher temperatures, but the carbon must be kept below 0.2. The third is the 70,000-lb plain carbon steel now used extensively for boiler drums. In this the carbon content is limited to 0.35, the manganese to 0.90 and the silicon to 0.30.

For welding, the chromium content should be low and air-hardening steel should not be used. When welding an alloy steel the rate of travel of the welding torch should be reduced in order to reduce the rate of cooling and to preheat the base metal. This is especially true with metal-arc welding which has localized application of heat whereas with gas welding there is more preheating

of the base metal. For this reason the latter method is better adapted to welding high alloy steels. Furthermore, the carbon content of the steel should not exceed about 0.25.

Increased strength is accompanied by decreased ductility, as by the addition of carbon, but the addition of small amounts of certain alloying elements permits increasing the tensile strength without too greatly decreasing the ductility. Manganese produces a coarse grain whereas vanadium produces a small grain.

Dr. Hodge then explained how the addition of certain elements effects an increase in the tensile strength, some by solution in the ferrite, others by affecting the carbite, some by producing a refinement in grain size and others by hardenability.

W. B. Miller stated that high-strength low-carbon alloy steels are excellent for welding. Nickel-chromium steel shows a rising yield point after stress-relieving at 1200 F, but if the temperature be increased to 1600 F it will show a lower strength. Moreover, for high-temperature service the weld material should be approximately the same as the base metal because of creep possibilities. He further discussed welding technique for pressure vessels intended for low-temperature service.

Non-Destructive Testing of Welds

Dr. Comfort A. Adams discussed the non-destructive testing of welds, reviewing the applicability and limitations of the several methods in use. As to radiography, he compared results with X-rays and gamma rays and stated that if one could get the same intensity with gamma rays they would be superior to X-rays, but this is impossible. He also explained the action of the Buckey grid as commonly used in the X-ray examination of welds.

The stethoscopic method is very limited as it will not detect certain types of defects.

The magnetic method also has limitations because of possible different magnetic properties of the weld and the base metal.

Also, the magniflux does not sharply define as the crack becomes deeper and is of no value in revealing slag inclusions, etc.

He showed a large number of slides of X-ray films and interpreted the character of defects revealed.

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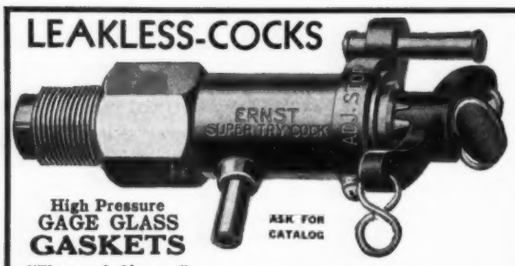

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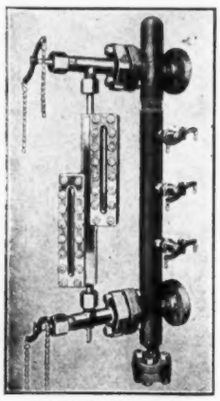

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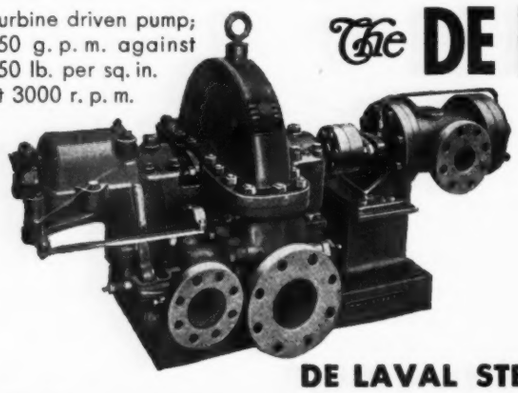

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Fuel Utilization in New York City

By ARTHUR C. STERN,

Superintendent, WPA Air Pollution Survey

The following is from a paper presented before the Annual Meeting of The Smoke Prevention Association at New York, June 3, 1937. The New York City U. S. Works Progress Administration Air Pollution Survey (Project 6164), sponsored by the New York City Health Department, was begun in September 1935 and now has a personnel of about one hundred engineers, chemists, draftsmen, field investigators, etc. Over 10,000 analyses of soot-fall, 4000 of atmospheric dust and 2000 of atmospheric pollen have been made. A major function of the project covers a fuel consumption and fuel-burning equipment survey.

NEW YORK CITY's energy for light, heat and power is derived almost entirely from fuels and none comes from locally produced water power; the 1/4 of 1 per cent that is derived from water power represents electricity generated outside the city limits and another 1/4 of 1 per cent is supplied by the combustion of waste fuels and refuse. Thus 99.5 per cent of all the energy in the form of electricity, gas and heat is supplied by coal, coke and and liquid fuel. Of this, approximately three-fourths represents coal and coke (52.6 per cent anthracite, 46.3 per cent bituminous and 1.1 per cent coke) and one-fourth oil (including fuel oil, gas oil and gasoline). In other words, expressed in general

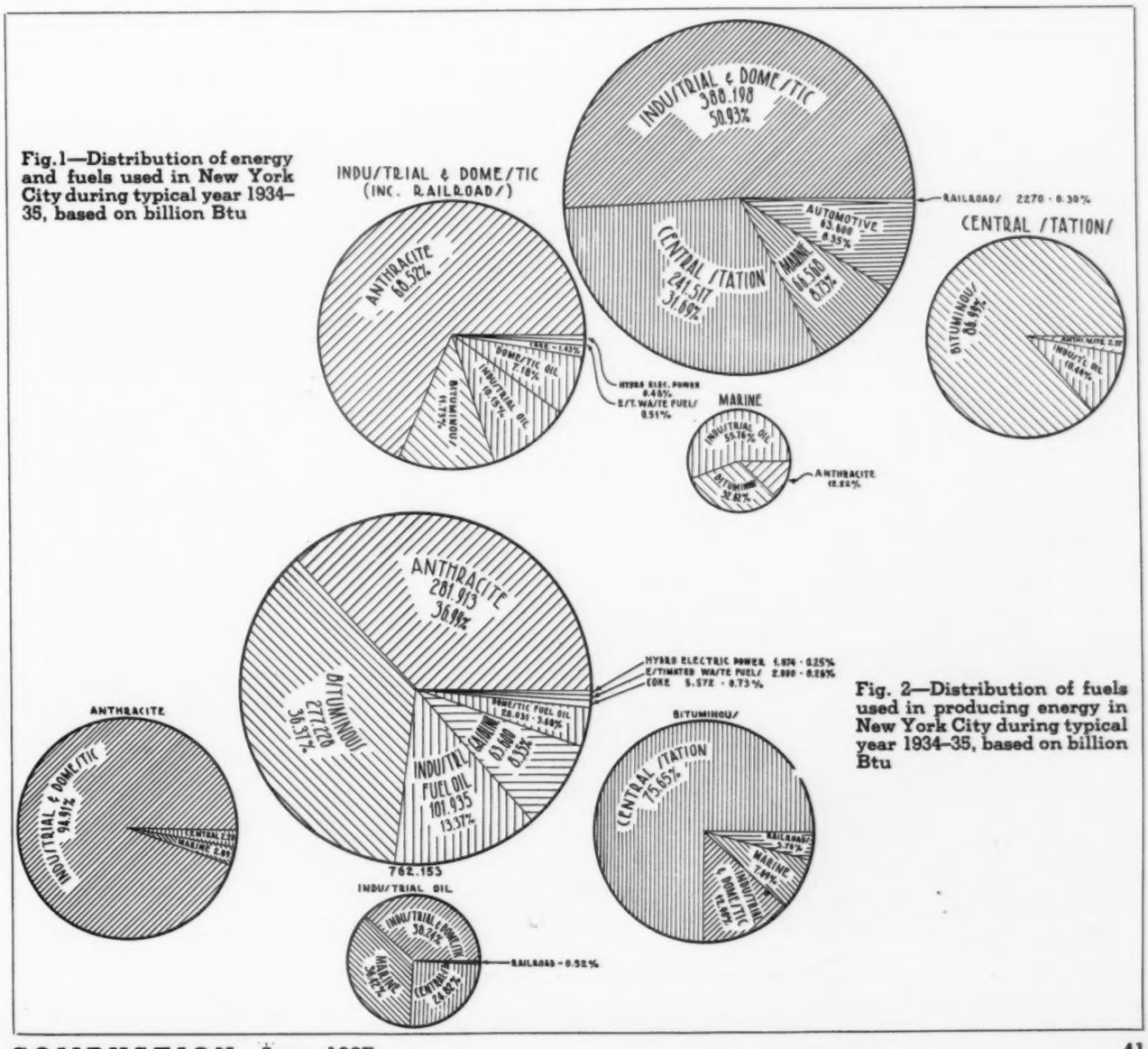

Fig. 1—Distribution of energy and fuels used in New York City during typical year 1934–35, based on billion Btu

Fig. 2—Distribution of fuels used in producing energy in New York City during typical year 1934–35, based on billion Btu

terms, the gross fuel and energy picture becomes three-eighths anthracite, three-eighths bituminous, one-eighth oil and one-eighth gasoline.

An idea of the enormous quantities of energy involved may be gained by noting that in 1935 the estimated total energy consumption (fuels and water power) of the entire United States was equivalent to 21,443 trillion Btu of which New York City accounted for $3\frac{1}{2}$ per cent.

TABLE I—DISTRIBUTION OF GAS, ELECTRICITY AND STEAM PRODUCED IN CENTRAL STATIONS

	Units	Quantity	Billions Btu
Electricity Generated	10^6 KWH	9,550	32,575
Steam Generated	1000 lb	11,950,771	15,145
Coke Oven Gas Generated	1000 Cu Ft	24,063,828	12,600
Carb. Water Gas Generated	1000 Cu Ft	46,393,738	27,800
Total Gas Generated	1000 Cu Ft	70,457,566	40,400
Coke Produced	1000 Net Tons	1,536	38,500
Coke to Water Gas	1000 Net Tons	805	20,126
Coke Sold	1000 Net Tons	731	18,374

The 20 million tons of coal consumed in the city represents about 5 per cent of all the coal mined in the United States and New York City consumes 20 per cent of all the hard coal mined.

Most of the gasoline is used in motor vehicles and the marine field accounts for 17.3 per cent of the fuel oil and 5 per cent of the coal entering the city. About 45 per cent of the liquid fuel is burned in stationary plants and for domestic use.

The best estimates place 2 per cent of the available energy, in the form of electricity, as being required to run the subways, elevated lines and trolley cars. This added to that utilized in the automotive and marine fields makes transportation account for about 19 per cent of the total energy.

Gas, electricity (excluding electric railways) and centrally generated steam account for 22.4 per cent of the total energy from the fuel, and 51.9 per cent is utilized in homes, offices and factories. In terms of fuel consumed, central stations account for 35 per cent of the coal and 12 per cent of the liquid fuel (the latter mainly in gas works). Almost half of the anthracite used in the city is in steam sizes and 90 per cent of the bituminous is run of mine. Of the latter, over 90 per cent is burned in the central stations.

TABLE II—FUEL AND ENERGY USED IN CENTRAL STATIONS

	Coal—1000 Tons				Oil—1000 Gals.			
Type	Gas Generating	%	Electricity Generating	%	Steam	%	Total	%
Anthracite	....	0.00	....	0.00	239	100.00	239	100.00
Bituminous	2,034	28.13	4,623	63.92	575	7.95	7,232	100.00
Oil	156,819	99.80	271	0.17	37	0.03	157,127	100.00
	Energy—Billions—Btu							
Anthracite	....	0.00	....	0.00	6,214	27.14	6,214	2.57
Bituminous	58,986	70.11	134,443	0.03	16,675	72.83	210,104	86.99
Oil	25,150	29.89	43	99.97	6	0.03	25,199	10.44
Total	84,136	100.00	134,486	100.00	22,895	100.00	241,517	100.00

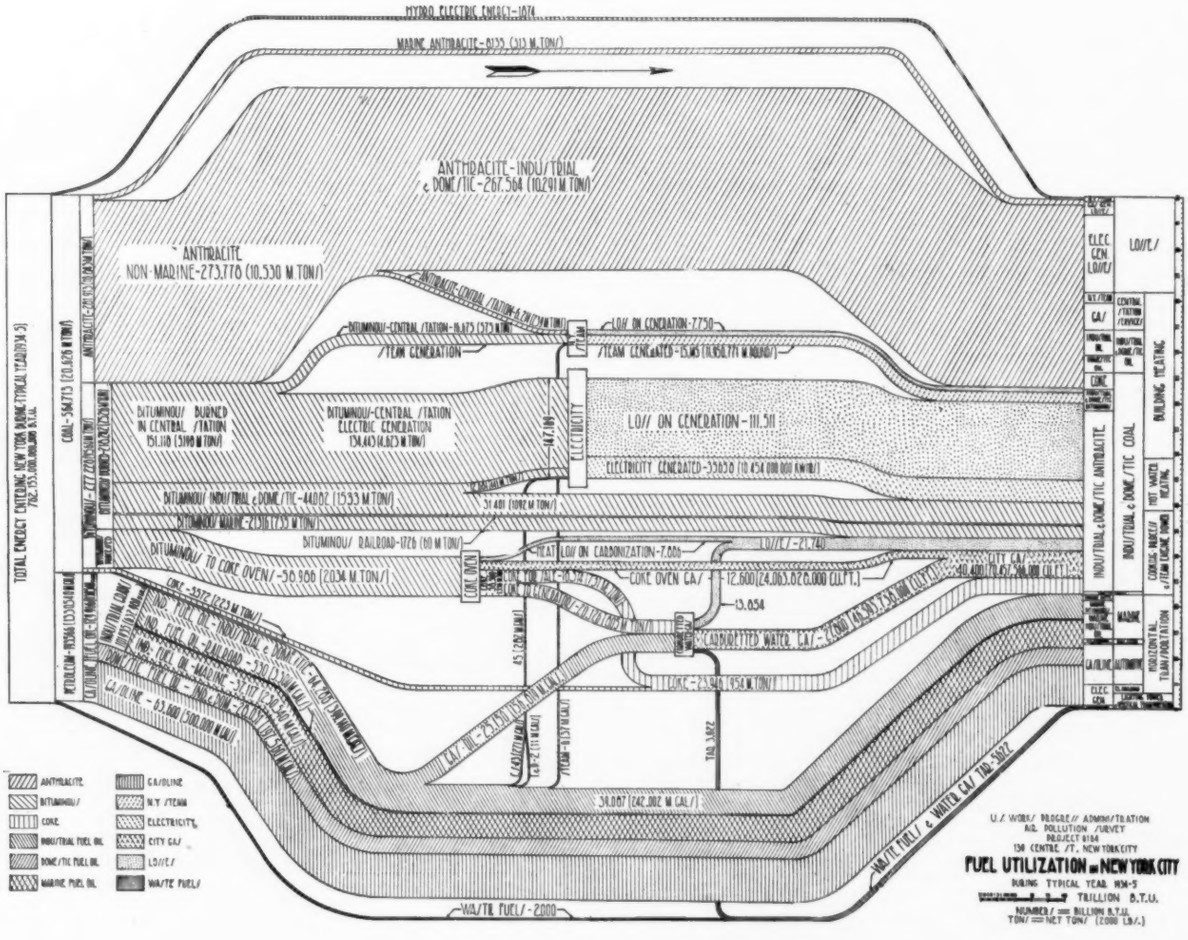

Fig. 3—Flow diagram of fuel used in New York

STEAM ENGINEERING ABROAD

As reported in the foreign technical press

Experiences in Operation with Slagging Bottom Furnaces

A report to the Reichskohlenrat of Germany, printed in *Archiv für Wärmewirtschaft und Dampfkesselwesen* for May 1937, reviews the operating experiences of three boiler installations having slagging bottoms. As will be noted from the illustrations, the construction closely resembles American practice.

The fuels fired were Bohemian hard coals and brown coal-lignite. The hard coal ash has a softening temperature of between 2120 and 2440 F and a melting temperature of between 2150 and 2460 F, and the ash content is relatively high, ranging from 15 per cent to 30 per cent. The brown coal, containing 9.8 per cent ash and 32 per cent water was successfully burned, its ash softening and melting temperature lying between 2060 and 2150 F.

Past operation with these coals demonstrated that the slag can be drawn off in a fluid state even at a minimum load of 30 to 40 per cent of rated capacity. There have not been any operating difficulties worth mentioning during normal load conditions. The ignition of the pulverized fuel at very low loads proved to be a particular advantage of the slagging bottom and due to the high furnace temperature, combustion continued without interruption.

According to operating reports, the boiler with a slagging bottom is more difficult to adapt to rapid load changes than one with a "dry" bottom. As the load falls off the accumulated heat in the slag generates an excess of steam, and as the load rises a portion of the delivered heat is consumed in "melting" the slag bed.

The maintenance of the slag bed supporting structure and the furnace walls is most vital. The slag pan, which is partly water cooled and partly air cooled, rests upon a heavy structural support and is packed with chrome-magnesite or built up in laminated fashion with refractory, magnesite or carborundum blocks and provided with a fireproof deck layer. To avoid the attack of the fresh unsaturated slag, the adaption of a so-called slag pool has been established; that is, after drawing off the slag there remains a sufficient amount to cover the slag pan floor. The difficulties which frequently resulted from the growth of the slag bed during alternate cooling and reheating, seem to have been overcome by maintaining a minimum depth of slag bed. The forces that appear during heating up are reduced thereby and become controllable. The slag tap must be carefully constructed with this type of firing. During operation it must be airtight in order to avoid "freezing" of the slag by the cold air so as to assure continuity of operation. On the other hand, the outflowing slag must be definitely chilled and only sufficient cooling water will guard against damage by the fluid slag.

The furnace walls are entirely water cooled. To reduce the heat absorption and to correspondingly raise the temperature of the melting zone, some of the boilers have pins provided on the wall tubes to more easily accumulate slag thereon. The adhering slag serves as a guard against chemical and mechanical attack. Even with 0.8 in. distance between tubes destruction of the refractory has been observed when no other protection was present.

The relation between the type of coal, the boiler load and the height of the furnace chamber is given in the report in terms of the permissible boiler loads when firing hard coal and brown coal. While 132,500 lb of

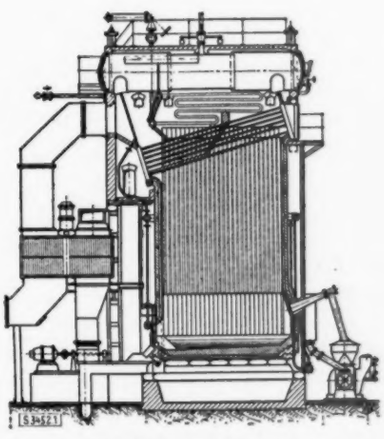

Fig. 1—66,000-lb per hr, 230-lb pressure unit with furnace heat release of 22,000 Btu per cu ft

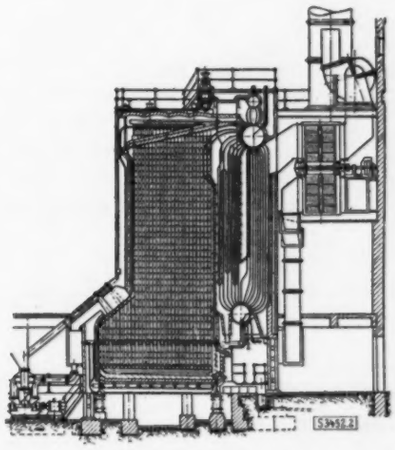

Fig. 2—132,000-lb per hr, 570-lb pressure unit with furnace heat release of 19,800 Btu per cu ft

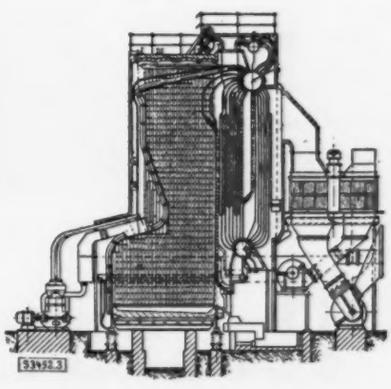

Fig. 3—132,000-lb per hr, 710-lb pressure unit with furnace heat release of 26,000 Btu per cu ft, average

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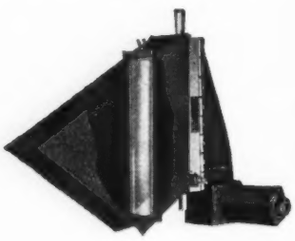

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steam per hour could be generated without difficulty when using hard coal, only 100,000 to 110,000 lb per hr could be carried with the brown coal since at higher loads the brown coal rapidly slags the heating surfaces because of its low ash softening temperature.

It becomes the function of the furnace chamber then to cool the products of combustion to such an extent that slag particles entering the heating surfaces have lost their ability to adhere. The higher the furnace loading, the higher the temperature of the slag melting zone and the greater the quantity of gas passing through the furnace; the lower the slag softening temperature, the higher must be the combustion chamber.

The direction of the flame in slagging furnaces must be very carefully supervised so that as little coke as possible falls into the slag bed. The coke may, under certain circumstances, reduce the iron present in slag as a consequence of which a heavily flowing slag may form as well as iron lumps which are difficult to remove.

Superposed Marine Installation on the Conte Rosso

In a paper before the Institute of Marine Engineers on March 9 at London, S. McEwen described and discussed the performance of the superposed Loeffler boiler installation on the Italian liner, Conte Rosso. This ship originally was equipped with 200-lb pressure Scotch marine boilers, one of which (of 16,000 lb per hr capacity) was replaced last August by a 44,000-lb per hr Loeffler unit operating at 1850 lb pressure and 890 F total steam temperature. Steam from this high-pressure boiler passes to two Escher Wyss high-pressure turbines in series, the first taking steam at boiler pressure and exhausting at 660 lb to the second unit which, in turn, exhausts through a steam reheater to the original 200 lb turbines. The high-pressure turbines are each coupled through gearing to a propeller shaft. An emergency reducing valve is fitted to supply the low-pressure turbines with steam from the Loeffler boiler if necessary.

The total weight of the high-pressure boiler unit, including radiant and convection superheaters, economizer, Ljungstrom air heater, feed and steam circulating pump, as well as fittings, is 53 tons which is equivalent to 1.2 tons per 1000 lb of steam.

The power requirement of the steam circulating pump is reported as representing 1.56 per cent of the boiler output which, if allowance be made for the recovered heat of compression, reduces to 1.1 per cent. When operating at 44,000 lb of steam per hour a gross boiler efficiency of 90 per cent is reported with feedwater from the economizer at 464 F, the stack gases leaving at 300 F and 12 per cent CO_2.

Standby Station Arranged for Instantaneous Starting

The review issue of *The Brown Boveri Review* contains a novel scheme for a standby power station to pick up load instantaneously and thus prevent interruption of power delivery on the system. In this arrangement the Velox boiler, which is a quick-starting unit requiring normally from 5 to 8 min to take over full load, is supplemented

by a relatively small high-pressure steam accumulator. Referring to the sketch, the boiler is designed for operation at 24 kg per sq cm abs (about 340 lb) and the accumulator is charged up to 130 kg per sq cm abs (about 1850 lb), by means of an auxiliary oil-burning equipment.

During the standby period the turbine is driven at normal speed by its generator, running as a phase advancer, and the main steam valve is open, but the governing valves are closed. The condenser works (with

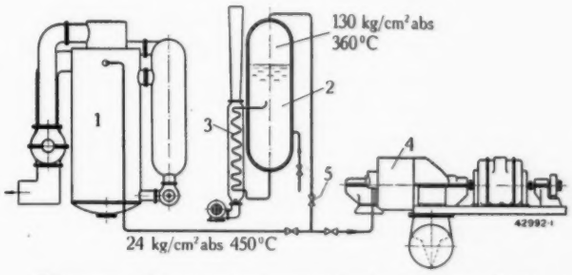

Diagram of instantaneous-starting power plant

1. Velox steam generator; 2. Accumulator; 3. Oil heating to charge accumulator; 4. Turbine-generator; 5. Reducing valve

reduced volume of circulating water) so that the turbine can run under vacuum with lower losses.

Should an interruption occur on the system the turbine governing valves will open and the turbine will take steam from the accumulator through a reducing valve until the Velox generator is ready to take over the load. This is started automatically by making the valves of its gas turbine (which drives the compressor for charging the combustion chamber) open at the same time as the governing valves of the steam turbine, and by making the charging and pump set run on steam from the accumulator. In this way the Velox generator can be brought up to full delivery in 3 to 4 min, especially as the accumulator keeps it under pressure during the idle period.

Large Cooling Tower at Blackburn Meadows

A cooling tower of 3,370,000 gal per hr is being erected at the Blackburn Meadows Power Station of the Sheffield Corporation Electricity Department. Its height will be 250 ft from pond level and its external diameters will be 155 ft at the base and 79 ft at the top. It is constructed of reinforced concrete and will weigh, with the foundations, about 4000 tons.—*Industrial Britain*, May 1937.

Another Unit for Battersea

According to an item in the April issue of *Engineering and Boiler House Review*, it is proposed to extend the capacity of Battersea Station of the London Power Company by the installation of a second 105,000-kw turbine-generator and additional boilers. This will represent the commencement of the second half of this station and will bring its capacity up to 350,000 kw. The first 105,000-kw unit went into service late last year.

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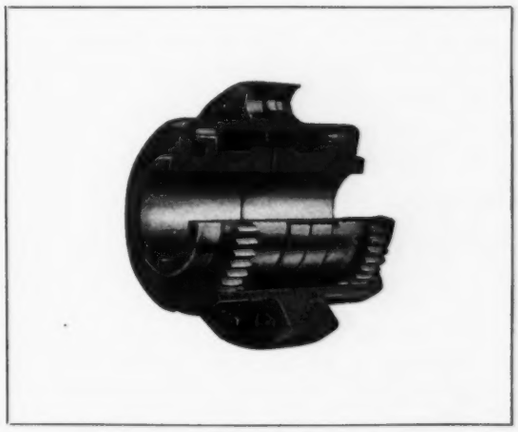

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REVIEW OF NEW BOOKS

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Heat Transfer in Boilers

By Loyd R. Stowe

Entitled "The Simple and Direct Answer to All Problems of Heat Transfer in Boilers," this 90-page multigraphed book, $8^1/_2 \times 11$ in., approaches the subject from the practical angle, through the use of charts and curves without resorting to involved mathematics such as are very common in heat-transfer problems. Information secured from about 500 boiler tests forms the basis of the material presented. Price $3.00.

Alignment Charts

By Paul N. Lehoczky

The Engineering Experiment Station of Ohio State University has issued a new handbook for the construction of nomographic charts. The purpose of the book is to teach the reader to construct a simple type of chart for any type of equation, no matter how involved, and to do this without the necessity of a theoretical background other than algebra. The alignment or nomographic chart is a device which minimizes the time required to solve recurring equations and eliminates practically all the mathematical work involved in a normal solution. Price 40 cents.

Questions and Answers on Boiler Feedwater Conditioning

By J. F. Barkley

This little book of 121 pages, in convenient pocket size with flexible binding, has been compiled under the direction of the U. S. Bureau of Mines to provide practical information to boiler operators who have not the advantage of a general knowledge of chemistry. In other words, it is an attempt to supplement their instructions on *how* to proceed with information on *why* the procedure is followed, so that they will not be working in the dark and will thus be better able to work effectively. For this purpose the question and answer form of presentation is well adapted. The booklet may be obtained from the Superintendent of Documents, Washington, D. C., for 20 cents.

Water Treatment and Purification

By William J. Ryan

The aim of the author in preparing this first edition of the book has been to present a summary of the various methods of water treatment and purification in a way that may be readily grasped by the average power engineer. To this end the construction and operation of the different types of filtering, softening and treating equipment are described and illustrated by both photographs and diagrams. Chapters include, the impurities in water, sedimentation and coagulation, filtration, analysis of water, lime and soda-ash process, the zeolite process, boiler feedwater treatment, disinfection of water and the prevention of corrosion. While the broad subject of treatment of water supply is dealt with, the major portion of the text is applicable to water problems encountered in steam generation.

There are 242 pages, $5^1/_2 \times 8$ in.; price $2.50.

Steam Power Stations

By Gustaf A. Gaffert

Written primarily as a textbook, the material is presented largely from the descriptive angle inasmuch as the author's long teaching experience has indicated that the engineering student desires to know how a thing is built. This applies to the various equipment entering into the complete power plant. Problems are included. Economics are dealt with to some extent in a chapter on load curves and plant location and another chapter deals with steam-station costs. Inasmuch as many of the figures quoted are several years old the latter chapter must be interpreted in the light of present costs to be of material value to the designing engineer. It is unfortunate that the time apparently involved in the preparation of the text has precluded the inclusion of designs that are involved in the more recent high-pressure, high-temperature installations, that is, those of the past two or three years, which mark a distinct departure from former practice. The last three chapters deal with heat cycles and station design.

The book covers 559 pages; 6×9 in.; price $4.50.

Heat Transfer in Evaporation and Condensation

By Max Jakob

This is a reprint by the University of Illinois Engineering Experiment Station of a series of lectures delivered by this well-known German authority before several educational institutions and engineering bodies about a year ago. The author has since taken up residence in this country in educational work.

The first lecture deals with research work on evaporation, progress in the measurement of latent heat and specific volume of saturated steam, calorimetric measurements at high pressures and experiments on superheating water in the calorimeter. The second deals with evaporation as a problem of heat transfer and qualitative results. The third covers photographic, stroboscopic and cinematographic experiments and their evaluation. The fourth deals with condensation; the fifth and sixth with experiments on film condensation and some deviations from Nusselt's theory. The price of this 75-page booklet is 35 cents.

Engineering Thermodynamics

By Newton C. Ebaugh

Based on his experience in teaching engineering students, Professor Ebaugh has adopted a sequence of presenting the fundamentals of thermodynamics that appears both logical and concise. This sequence takes up thermodynamics and energy, state of a fluid and changes of state, gas properties and processes, cycles and available energy, entropy, vapor properties and processes, gas and vapor mixtures, flow of fluids, vapor power cycles, internal combustion cycles, gas compression and refrigeration cycles. Many problems are included as well as a psychrometric chart, a Mollier Chart on the properties of ammonia and a large Mollier Chart on the properties of steam, based on the latest Keenan and Keyes steam values.

Much of the treatment is mathematical and no attempt has been made to apply the theory to engineering equipment, inasmuch as the author believes this to belong properly in courses and books on steam power engineering.

The book contains over 200 pages, 6 × 9 in., with cloth binding. Price $2.85.

Thermodynamics, Fourth Edition

By Professor J. E. Emswiler

In the present edition of this well-known book there has been incorporated new matter on water vapor refrigeration and on the steam-air mixture, both topics being basic to the subject of air conditioning. Also, the material dealing with the energy laws of thermodynamics has been changed considerably and many new problems added.

Written primarily as a textbook for mechanical engineering students, the material is presented somewhat differently from that in the usual work on thermodynamics and it should also be found useful as a work of reference for the practicing engineer.

There are 351 pages, 6 × 9 in., bound in cloth. Price $3.00.

Steam Boilers

By Terrell Croft
Second Edition, Revised by R. B. Purdy

This book is one of a series on power plant subjects, first brought out about fifteen years ago, which had a wide circulation particularly among practical operating engineers in plants of small and medium size. In preparing the revision the same treatment has been followed but much of the text has been revised and brought up to date. It covers the various classes of steam boilers, firing equipment and boiler accessories, including chimneys and feedwater treatment.

Boiler construction and materials are discussed, some of the more common formulas are included, and excerpts from codes and inspection regulations are given. For the benefit of engineers who may be preparing for license examinations, selected questions and problems are appended at the end of each division.

The book contains 417 pages, 8 × 5 ½ in., bound in cloth. Price $4.00.

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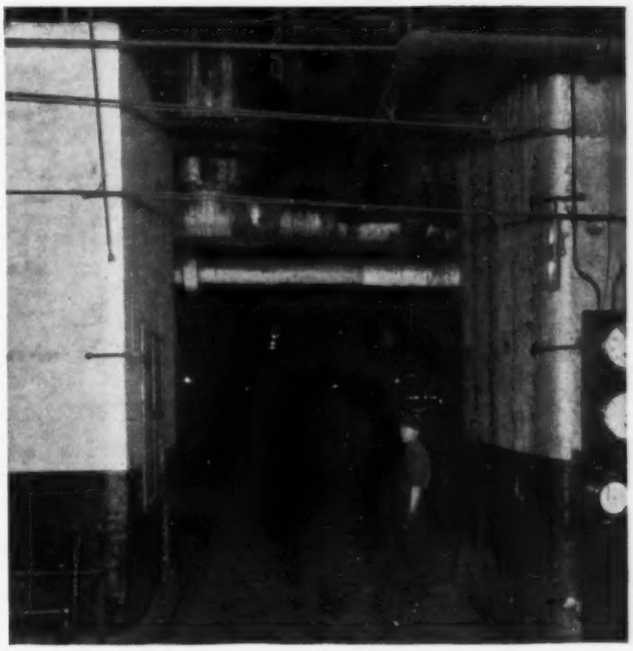

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ADVERTISERS

Air Preheater Corporation, The
Under Management of The Superheater Company 12
American Blower Corporation 11
Armstrong Machine Works 10
C. O. Bartlett & Snow Company, The ..... Fourth Cover
Bayer Company, The 10
Buromin Company, The 7
Cochrane Corporation 15
Combustion Engineering Company, Inc. ..... Second Cover, 8 and 9
De Laval Steam Turbine Company ..... 2 and 40
Eagle-Picher Lead Company, The 47
Edward Valve & Mfg. Company, Inc., The 5
Engineer Company, The 16
Ernst Water Column & Gage Company 40
General Coal Company 19
General Electric Company 16
Hagan Corporation 7
Hall Laboratories, Inc. 7
Hays Corporation, The 4
Ingersoll-Rand Company ..... Third Cover
Johnston & Jennings Company, The 13
Jones & Laughlin Steel Corporation 6
National Aluminate Corporation 20
Permutit Company, The ..... 17 and 18
Poole Foundry & Machine Company 45
Refractory & Insulation Corporation 10
Reliance Gauge Column Company, The 44
Republic Flow Meters Company 14
Cyrus Wm. Rice & Company, Inc. 3
W. A. Taylor & Company, Inc. 48
Vulcan Soot Blower Corporation 48
Yarnall-Waring Company 48

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General Index of Articles and Editorials

(COMBUSTION—Vol. 8, No. 1, July, 1936, to and including Vol. 8, No. 12, June, 1937)

EDITORIALS—

		Page
Advice to Engineering Graduates	(May 1937)	15
Behind the Scenes	(Feb. 1937)	21
Canadian Engineers Celebrate Semi-Centennial	(June 1937)	21
Central Heating Prospects	(Jan. 1937)	19
Cinder and Dust Recovery	(Dec. 1936)	15
Coal per Kilowatt-Hour	(Nov. 1936)	21
Distorted Information	(Aug. 1936)	13
Domestic Oil Burners	(Dec. 1936)	15
Economist Compares Steam and Water Power, An	(Mar. 1937)	19
Engineer and Labor Problems, The	(June 1937)	21
Engineering Unemployment during the Depression	(Mar. 1937)	19
Federal Power Commission Rate Survey	(July 1936)	17
Heat Balance Tests	(Apr. 1937)	21
High-Speed Hydrogen-Cooled Turbine-Generators	(Oct. 1936)	17
Hydro Power Abroad	(Sept. 1936)	19
Load Ahead of Capacity Increase	(Jan. 1937)	19
Molybdenum as a Catalyst	(Apr. 1937)	21
Net or Gross Efficiency	(Sept. 1936)	19
New Steam Table Values in the Higher Ranges	(Oct. 1936)	17
New York Power Show, The	(Nov. 1936)	21
Not Class I Welding	(Nov. 1936)	21
Plant Data	(Feb. 1937)	21
Revised Boiler Tube Thicknesses	(Feb. 1937)	21
Stack Discharges Receiving Attention	(July 1936)	17
Station Performance Here and Abroad	(July 1936)	17
Steam Generating Unit Design	(Dec. 1936)	15
Steel Deliveries	(Apr. 1937)	21
"Tailor-Made" Installations	(Oct. 1936)	17
Utility Accidents	(Aug. 1936)	13
Vocational Guidance	(Aug. 1936)	13
Where National Defense Dominates Engineering Thinking	(June 1937)	21
When Shutting Down Mills	(Jan. 1937)	19
World Power Conference, The	(Sept. 1936)	19

ARTICLES—

		Page
Alabama Coals—Their Classification and Analyses. By P. B. Place	(Jan. 1937)	40
Auxiliaries—Steam or Electric Drive? By Theodore Baumeister, Jr	(Mar. 1937)	25
Benson Boiler, The. By Dr. F. Michel	(July 1936)	27
Boiler Baffling Arrangements. By W. S. Patterson	(June 1937)	29
Boiler Code Proposals and Welding Research. By D. S. Jacobus	(June 1937)	35
Boiler Inspectors Meet at New York	(June 1937)	35
Central Station Flow Diagrams	(Jan. 1937) and (May 1937)	25 21
Chlorination of Spray Pond Water, The	(Aug. 1936)	18
Circulation in Water-Tube Boilers	(Oct. 1936)	35
Coal Handling Improvements at the Miller's Ford Station, Dayton, O. By R. D. Gillespie	(Nov. 1936)	41
Combustion Instruments and Control at Hell Gate. By Paul W. Keppler	(Apr. 1937)	29
Creep and Corrosion Discussed at International Congress	(May 1937)	29
Design of High-Pressure Boilers. By E. Lupberger	(Jan. 1937)	33
Developments in Steam Generating Units. By John Van Brunt	(June 1937)	37
Developments in the Battle against Corrosion. By V. A. Rohlin and C. E. Joos	(July 1936)	22
Dust-Prevention Treatment of Solid Fuels. By L. D. Schmidt	(Feb. 1937)	39
Economizer Maintenance	(Nov. 1936)	26
Electric and Water Services Crippled by Flood at Cincinnati	(Feb. 1937)	25
Equipment and Operating Data on the Federal Central Heating Plant. By J. F. Barkley and Charles A. Peters, Jr.	(Nov. 1936)	27
Experience with Combustion Control. By T. E. Crossan and A. J. Matherne, Jr.	(July 1936)	35
Fabrication of High-Pressure Drums for Waterside Boilers	(Jan. 1937)	38
Factors in the Design of Superposed Turbines. By H. L. Wirt	(Nov. 1936)	22
Flue Gas Separators. By K. Heinrich	(Feb. 1937)	36
Forced-Circulation Boilers. By H. B. Oatley	(June 1937)	35
Ford to Add Another High-Pressure Unit	(May 1937)	36
Fuel Utilization in New York City. By Arthur C. Stern	(June 1937)	41
Heat Losses in Flue Gases of Stoker-Fired Boilers. By Dr. A. H. Moody and J. A. Harrington	(Nov. 1936)	33
Heater Closures. By George A. Fricke	(Mar. 1937)	31
High-Pressure Installation at Mannheim. By Gerhard Kordes	(Dec. 1936)	16
High Spots of German Power Plant Practice. By Dr. Ing. Otto Schöne	(Oct. 1936)	29
How Engineers May Profit from Patented Inventions. By Leo T. Parker	(Mar. 1937)	37
Incipient Boiler Failures. By D. L. Royer	(July 1936)	31
Kansas and Missouri Coals—Their Classification and Analyses. By P. B. Place	(Apr. 1937)	37
Law as Applied to Trade-Marks and Trade Names, The. By Leo T. Parker	(Oct. 1936)	41
Law of Tools and Equipment, The. By Leo T. Parker	(Dec. 1936)	33
Load Distribution for Best Overall Economy. By E. D. St. John	(Sept. 1936)	30
Maintaining High Standards for Welded Vessels. By A. C. Weigel	(June 1937)	39
Maryland Coals—Their Classification and Analyses. By P. B. Place	(Oct. 1936)	37
Model of Conners Creek Boilers	(Apr. 1937)	36
Modifications of the Hot Process When Conditioning Makeup for High-Pressure Boilers. By C. E. Joos	(Oct. 1936)	32
Newer Methods of Sulphate Determinations and Their Application to Plant Control. By L. Drew Betz	(Sept. 1936)	43
Non-Destructive Testing of Welds. By Dr. Comfort A. Adams	(June 1937)	40
Observations of Flowing Steam. By John I. Yellott	(May 1937)	16
Operation of Large Modern Steam Generating Units. By E. H. Krieg	(June 1937)	37
Paralleling Feed Pumps	(July 1936)	26
Performance of Some American Power Stations	(Sept. 1936)	28
Power and People. By John C. Parker	(Feb. 1937)	22
Power Development in Russia	(Nov. 1936)	39
Power Resources and Practice in Germany	(Sept. 1936)	23
Prevention of Furnace Explosions. By E. G. Bailey	(June 1937)	38
Prevention of Spontaneous Heating of Large Coal Piles. By M. K. Drewry	(Feb. 1937)	28
Problems in Collection and Evaluation of Data for the Design of Steam Generating Units. By B. J. Cross	(Dec. 1936)	23
Production of Electricity and Consumption of Fuels	(Feb. 1937)	32
Random Views of the New York Power Show	(Dec. 1936)	32
Rating and Performance of Stationary Steam Boilers. By W. S. Patterson	(Aug. 1936)	23
Regulation of Feedwater Level in Boilers. By V. V. Veenschoten	(Mar. 1937)	34
Relation of Burning Equipment to Coal Selection. By E. C. Payne	(May 1937)	34
Round Table Conferences	(Oct. 1936)	18
Semi-Outdoor Station Placed in Service	(Aug. 1936)	14
Size Versus Unit Cost of Steam Generating Units	(Oct. 1936)	28
Sodium Sulphite for Removal of Oxygen	(Sept. 1936) and (Nov. 1936)	25 25
Some Factors Influencing Design of Pulverized-Coal-Fired Steam Generating Units. By Otto de Lorenzi	(Feb. 1937)	33
Some High Spots of the A.S.M.E. Annual Meeting	(Dec. 1936)	20
Some Recent Developments in Operation and Maintenance of Surface Condensers. By A. H. Moody	(Aug. 1936)	19
Some World Power Conference Delegates on Tour III	(Sept. 1936)	27
Specific Enthalpy of Low-Pressure Steam, The. By C. Harold Berry	(Apr. 1937)	41
Steam Turbine Regulation and Supervisory Control. By A. F. Schwendner, A. A. Luoma, J. L. Roberts and C. D. Greentree	(Dec. 1936)	29
Steam vs. Hydro Power in France	(Sept. 1936)	46
Superposition at Schuylkill Station of Philadelphia Electric Company. By E. L. Hopping	(June 1937)	22
Tennessee Coals—Their Classification and Analyses. By P. B. Place	(Sept. 1936)	37
Test of Unit No. 5 at Rouge Plant of the Ford Motor Company. By W. W. Dulmage	(Apr. 1937)	22
"Topping" Extension to Omaha Steam Plant. By Louis Elliott	(Sept. 1936)	20

PAGE

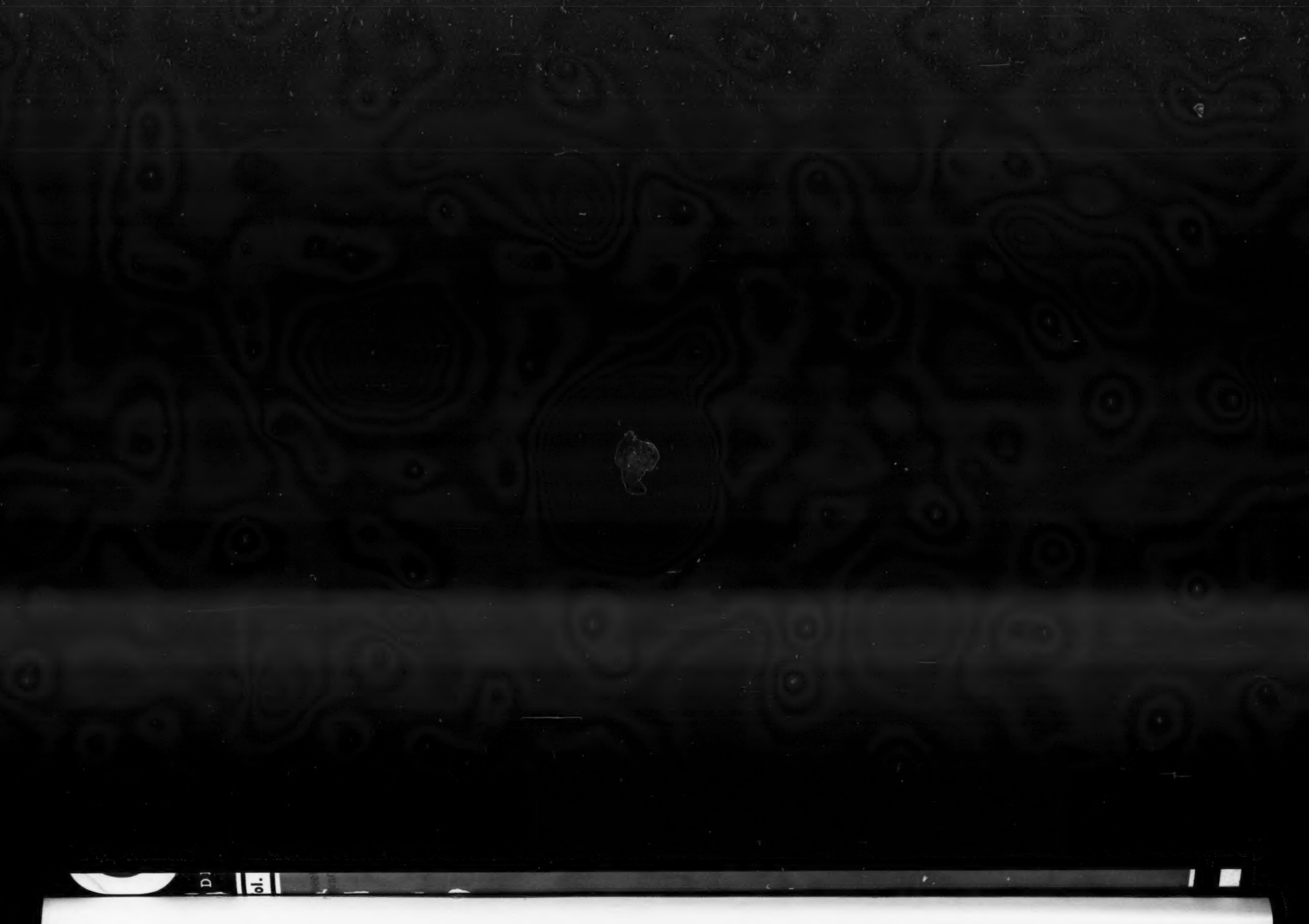
Trends and Developments in Industrial Turbines. By E. R. Kauffman. (Jan. 1937) 20
Twenty-Five Years of Power Development. By A. G. Christie... (Apr. 1937) 34
Unusual Boiler Problems Caused by Corrosion. By Cyrus Wm. Rice. (Aug. 1936) 31
Waterside High-Pressure Turbine Nears Completion. (May 1937) 32
Welding High Tensile Strength, Low Alloy Steels. By Dr. J. C. Hodge. (June 1937) 39
Windsor Steam Plant Modernization. By Philip Sporn. (Mar. 1937) 20
World Power Conference. (July 1936) 18

AUTHORS—

Adams, Dr. Comfort A.—Non-Destructive Testing of Welds. (June 1937) 40
Bailey, E. G.—Prevention of Furnace Explosions. (June 1937) 38
Barkley, J. F.—Equipment and Operating Data on the Federal Central Heating Plant. (Nov. 1936) 27
Baumeister, Theodore, Jr.—Auxiliaries—Steam or Electric Drive? (Mar. 1937) 25
Berry, C. Harold—The Specific Enthalpy of Low-Pressure Steam (Apr. 1937) 41
Betz, L. Drew—Newer Methods of Sulphate Determinations and Their Application to Plant Control. (Sept. 1936) 43
Christie, A. G.—Twenty-Five Years of Power Development. (Apr. 1937) 34
Cross, B. J.—Problems in Collection and Evaluation of Data for the Design of Steam Generating Units. (Dec. 1936) 23
Crossan, T. E.—Experience with Combustion Control. (July 1936) 35
de Lorenzi, Otto—Some Factors Influencing Design of Pulverized-Coal-Fired Steam Generating Units. (Feb. 1937) 33
Drewry, M. K.—Prevention of Spontaneous Heating of Large Coal Piles. (Feb. 1937) 28
Dulmage, W. W.—Test of Unit No. 5 at Rouge Plant of the Ford Motor Company. (Apr. 1937) 22
Elliott, Louis—"Topping" Extension to Omaha Steam Plant. (Sept. 1936) 20
Fricke, George A.—Heater Closures. (Mar. 1937) 31
Gillespie, R. D.—Coal Handling Improvements at the Miller's Ford Station, Dayton, O. (Nov. 1936) 41
Harrington, J. A.—Heat Losses in Flue Gases of Stoker-Fired Boilers. (Nov. 1936) 33
Heinrich, K.—Flue Gas Separators. (Feb. 1937) 36
Hodge, Dr. J. C.—Welding High Tensile Strength, Low Alloy Steels. (June 1937) 39
Hopping, E. L.—Superposition at Schuylkill Station of Philadelphia Electric Company. (June 1937) 22
Jacobus, D. S.—Boiler Code Proposals and Welding Research. (June 1937) 35
Joos, C. E.—Developments in the Battle against Corrosion. (July 1936) 22
Modifications of the Hot Process When Conditioning Makeup for High-Pressure Boilers. (Oct. 1936) 32
Kauffman, E. R.—Trends and Developments in Industrial Turbines. (Jan. 1937) 20
Keppler, Paul W.—Combustion Instruments and Control at Hell Gate. (Apr. 1937) 29
Kordes, Gerhard—High-Pressure Installation at Mannheim. (Dec. 1936) 16
Krieg, E. H.—Operation of Large Modern Steam Generating Units (June 1937) 37
Lupberger, E.—Design of High-Pressure Boilers. (Jan. 1937) 33
Matherne, A. J., Jr.—Experience with Combustion Control. (July 1936) 35
Michel, Dr. F.—The Benson Boiler. (July 1936) 27
Moody, Dr. A. H.—Heat Losses in Flue Gases of Stoker-Fired Boilers. (Nov. 1936) 33
Some Recent Developments in Operation and Maintenance of Surface Condensers. (Aug. 1936) 19
Oatley, H. B.—Forced-Circulation Boilers. (June 1937) 35
Parker, John C.—Power and People. (Feb. 1937) 22
Parker, Leo T.—How Engineers May Profit from Patented Inventions. (Mar. 1937) 37
The Law as Applied to Trade-Marks and Trade Names. (Oct. 1936) 41
The Law of Tools and Equipment. (Dec. 1936) 33
Patterson, W. S.—Boiler Baffling Arrangements. (June 1937) 29
Rating and Performance of Stationary Steam Boilers. (Aug. 1936) 23
Payne, E. C.—Relation of Burning Equipment to Coal Selection. (May 1937) 34
Peters, Charles A., Jr.—Equipment and Operating Data on the Federal Central Heating Plant. (Nov. 1936) 27
Place, P. B.—Alabama Coals—Their Classification and Analyses (Jan. 1937) 40
Kansas and Missouri Coals—Their Classification and Analyses (Apr. 1937) 37
Maryland Coals—Their Classification and Analyses. (Oct. 1936) 37
Tennessee Coals—Their Classification and Analyses. (Sept. 1936) 37

PAGE

Rice, Cyrus Wm.—Unusual Boiler Problems Caused by Corrosion (Aug. 1936) 31
Rohlin, V. A.—Developments in the Battle against Corrosion (July 1936) 22
Royer, D. L.—Incipient Boiler Failures. (July 1936) 31
St. John, E. D.—Load Distribution for Best Overall Economy. (Sept. 1936) 30
Schmidt, L. D.—Dust-Prevention Treatment of Solid Fuels. (Feb. 1937) 39
Schöne, Dr. Ing. Otto—High Spots of German Power Plant Practice. (Oct. 1936) 29
Sporn, Philip—Windsor Steam Plant Modernization. (Mar. 1937) 20
Stern, Arthur C.—Fuel Utilization in New York City. (June 1937) 41
Veenschoten, V. V.—Regulation of Feedwater Level in Boilers. (Mar. 1937) 34
Weigel, A. C.—Maintaining High Standards for Welded Vessels. (June 1937) 39
Wirt, H. L.—Factors in the Design of Superposed Turbines. (Nov. 1936) 22
Yellott, John I.—Observations of Flowing Steam. (May 1937) 16
Van Brunt, John—Developments in Steam Generating Units. (June 1937) 37

STEAM ENGINEERING ABROAD

Air Blast Pulverizer on Shipboard. (Dec. 1936) 36
Another Unit for Battersea. (June 1937) 45
Battersea Power Station and the Flue-Gas Problem. (Apr. 1937) 43
Boiler Plant Extension at Leicester. (Jan. 1937) 47
Boiler Testing by Chemical Method. (Feb. 1937) 45
Boiler Water Concentration with Loeffler Boilers. (Dec. 1936) 37
British Grid to Add Another 40,000 Kw. (Feb. 1937) 43
British to Erect New Station in Kent. (Oct. 1936) 45
Burning Mixed Coal Sizes on Traveling Grate. (Feb. 1937) 43
Closed-Air System of Transmission. (July 1936) 40
Coal vs. Oil for Merchant Ships. (May 1937) 39
Combustion under Pressure. (Feb. 1937) 43
Data on the Grid. (May 1937) 39
Detecting Cracks at Rivet Holes. (Dec. 1936) 35
Double Return-Tube Boiler. (Nov. 1936) 45
Electricity Supply Progress in France. (Aug. 1936) 37
Experiences in Operation with Slagging Bottom Furnaces. (June 1937) 43
Extension at Nottingham. (Dec. 1936) 35
Filming Combustion of Pulverized Coal. (Mar. 1937) 39
Flow in Steaming Tubes Arranged in Parallel. (May 1937) 37
Forced-Circulation, Once-Through and Natural-Circulation Boilers Compared. (Jan. 1937) 45
Fulham Power Station. (Nov. 1936) 46
Fumes from Battersea Station. (Jan. 1937) 45
German Views on Turbine Types. (May 1937) 40
Heating with Superheated Water. (Mar. 1937) 39
Heat Insulation. (Apr. 1937) 44
Heat Loss with Bare Flanges. (July 1936) 42
High-Pressure Marine Boiler. (Oct. 1936) 45
Increased Electric Output in British Empire. (July 1936) 40
Increased Power for South Africa. (Apr. 1937) 43
Interconnection in France. (Apr. 1937) 43
Kearsley Station. (Jan. 1937) 45
Large Cooling Tower. (Oct. 1936) 44
Large Cooling Tower at Blackburn Meadows Station. (June 1937) 45
Large Ljungström Turbines. (Apr. 1937) 43
Large Paper Mill Power Plant. (Oct. 1936) 45
Low Temperature Carbonization. (Oct. 1936) 44
Manufacture of Lubricants from Coal and Lignites. (Nov. 1936) 46
Material Requirements of the German Boiler Industry. (Apr. 1937) 43
New German Rules for Welded Steam Boilers. (Nov. 1936) 47
New Turbines for Japan. (Mar. 1937) 41
Performance at St. Denis. (Aug. 1936) 36
Performance of British Power Stations. (July 1936) 41
Power from Refuse Destructor. (Aug. 1936) 35
Ramsin High-Pressure Boiler, The. (Oct. 1936) 44
Rotary Economizer. (Nov. 1936) 45
6000-Kw Electric Boiler. (Aug. 1936) 35
Some British Power Statistics. (Nov. 1936) 45
Standby Station Arranged for Instantaneous Starting. (June 1937) 44
Steels for Modern Steam Conditions. (Nov. 1936) 45
Stud-bolt Material for High Temperatures. (Aug. 1936) 35
Superheat Control. (Mar. 1937) 41
Superposed Marine Installation on the Conte Rosso. (June 1937) 44
Tension on Turbine Casing Bolts. (Dec. 1936) 36
Tests on High-Pressure High-Temperature Turbine. (July 1936) 40
"Top" for British Industrial Plant. (Mar. 1937) 41
Treatment of Flue Gases. (Aug. 1936) 36
Tube Changes through Bending. (Mar. 1937) 39
Turbine Experience on the Queen Mary. (May 1937) 38
Waste Heat Installation. (Jan. 1937) 46
Water Softening on the Queen Mary. (Aug. 1936) 37